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Systems Evaluation of Low-Density Air Transportation Concepts

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Air Transportation Group

July 1972

Prepared for ADVANCED CONCEPTS AND MISSIONS DIVISION
NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
Moffett Field, California

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Civil Programs Division
THE AEROSPACE CORPORATION

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SYSTEMS EVALUATION OF

LOW-DENSITY AIR TRANSPORTATION CONCEPTS

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FOREWORD

This low-density air transportation study performed for the Advanced Concepts and Missions Division of NASA is directed at finding a solution to the growing rural transportation problems in the United States. It examines a variety of demographic, economic, and technical factors which influence the viability of the rural air transportation service.

A summary of the study, "Study of Low-Density Air Transportation Concepts," ATR-73(7304)-1, was published in July 1972. The purpose of this second volume of the report is to present the systems analysis and principal technical data developed during the low-density air transportation study. Appreciation is extended to Mrs. Susan Norman, the NASA Technical Monitor for the study, for her assistance and guidance provided.

Many members of the technical staff of The Aerospace Corporation participated in this study. Particular acknowledgment for valuable contributions is given to:

Leon R. Bush
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Jon R. Buyan and Daniel J. Cavicchio, Jr.
(Traveler mode choice analysis)

Ralph E. Finney
(Low-density arena demographics)

Joseph A. Neiss and Suzanne C. Miller
(Economics)

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I. INTRODUCTION

This study is devoted to seeking ways of improving air transportation to low-density population regions in the United States through the application of new aeronautical technology and operating methods. The difficulty of providing an adequate level of air service to rural America has been frequently observed in recent years and has most recently been restated in the Civil Aviation Research and Development (CARD) Policy Study.[1] In addition, there have been two recent studies[2,3] which highlighted both the need and the means for implementation of air transportation service to low-density areas. These studies pointed out the need for service, the economic problems associated with a low and dispersed demand, and the need for an air transportation system analysis to study operating system concepts, equipments, and passenger response to new forms of service. Airline service to rural America could conceivably be profitable if new aircraft designs optimized for economical operation of low-density routes could be made available to the operators at a reasonable cost. Additionally, schemes of airline operating using these improved aircraft and recent advances in communications and computers could be introduced to further minimize the operators' costs and provide attractive flight schedule possibilities to the public.

This study is divided into two study elements. The first element identifies the low-density air transportation arenas in the United States. This is accomplished by making a preliminary determination of the possible demographic conditions in rural regions that could support some form of air transportation and of the ranges of air transportation demand and service parameters appropriate in such rural regions. A review is then made of existing travel characteristics in these representative low-density

arenas. The data utilized includes that contained within the 1967 Census of Transportation,[4] the CAB Origin and Destination Survey of Airline and Passenger Traffic,[5] CAB traffic statistics,[6] and State Public Utilities records. Applicable data from the Western Region Study[7] is also utilized. In addition, investigations of trunk, local service, and commuter air carriers are made to identify the current techniques, equipment, and economics associated with contemporary low-density air service. This information is utilized and correlated against the characteristics of rural air transportation arenas to develop the present relationships among demographic characteristics, service features, and air travel demands that are peculiar to the low-density regions. The results are analyzed to establish the arena characterizations peculiar to low-density regions in the United States and a tabulation is made of the potential low-density air arenas.

The second element of the study is the arena system analysis which develops the characteristics of low-density air service concepts through the conduct of application studies in selected low-density regions of the United States. Additionally, this study element identifies critical technologies that presently limit the effective application of low-density air transportation systems. Two air service arenas are examined. One of these arenas is contained within the Western Region; the second is selected on the basis of diverse demographic, topographic, climatological, and socio-economic conditions. Economic analyses are conducted to establish a probable fare structure. The Aerospace Modal Split Program is used to estimate the air travel demand for each region utilizing total travel demands, probable fare structures, and minimum frequency of service. Alternative fare structures and frequency of service are evaluated to identify the preferred strategies for each arena.

Within each arena, a preliminary definition of a low-density air transportation system concept is then prepared. This concept definition includes both aircraft and preliminary operating procedures. The mid-1970 state-of-the-art forms the basis of these concept definitions. The operating cost of each system as well as the investment cost and schedule are estimated. The system characteristics influencing the economic viability and the market demand (such as frequency of service, fare structure, and schedule) are varied to establish for each arena a system configuration which offers (1) the greatest potential for successful air carrier service, and (2) one which can be used also to develop a data base for low-density air transportation problems on a national scale. In addition, "sensitivity" studies are included to identify those technologies which presently limit the application of air transportation concepts to low-density regions. The significance of improvements are noted and, to the degree that available technological information permits, new aircraft configurations especially suited to low-density service are identified.

II. METHODOLOGY

A. DEFINITION OF LOW-DENSITY ARENA

A study of the application of short-haul air transportation in a low-density arena requires a clear understanding and definition of low density. The primary regional characteristics that were considered are population density, trading areas, and air transportation hubs. However, for the study results to be both useful in defining low-density travel characteristics and compatible with future studies, the characteristics should be defined in terms of an available statistical data base.

The best available sets of demographic and traveler characteristic data with common definitions appear to be the 1970 Census of Population[8] and the 1967 Census of Transportation.[9] The population census provides the necessary statistical data for the examination of the demographics and economics by geographical region and also by urban or rural areas while the transportation census allows definition of the traveler's characteristics by the same categories. The definition of populated regions was therefore chosen to agree with the standard census definitions which are as follows: the high-density market, hereafter called urban, is associated with the Standard Metropolitan Statistical Area (SMSA); each SMSA includes a city of more than 50,000 population, the counties in which the city is located plus other counties that exhibit strong ties. The low-density market, hereafter called nonurban or rural, is the Non-Standard Metropolitan Statistical Area (NSMSA); the NSMSAs including all towns of less than 50,000 population in all areas outside of the SMSAs. In terms of population in the United States, two-thirds live in urban areas and one-third in the rural or nonurban areas. The urban and rural areas are shown in Figure 1.

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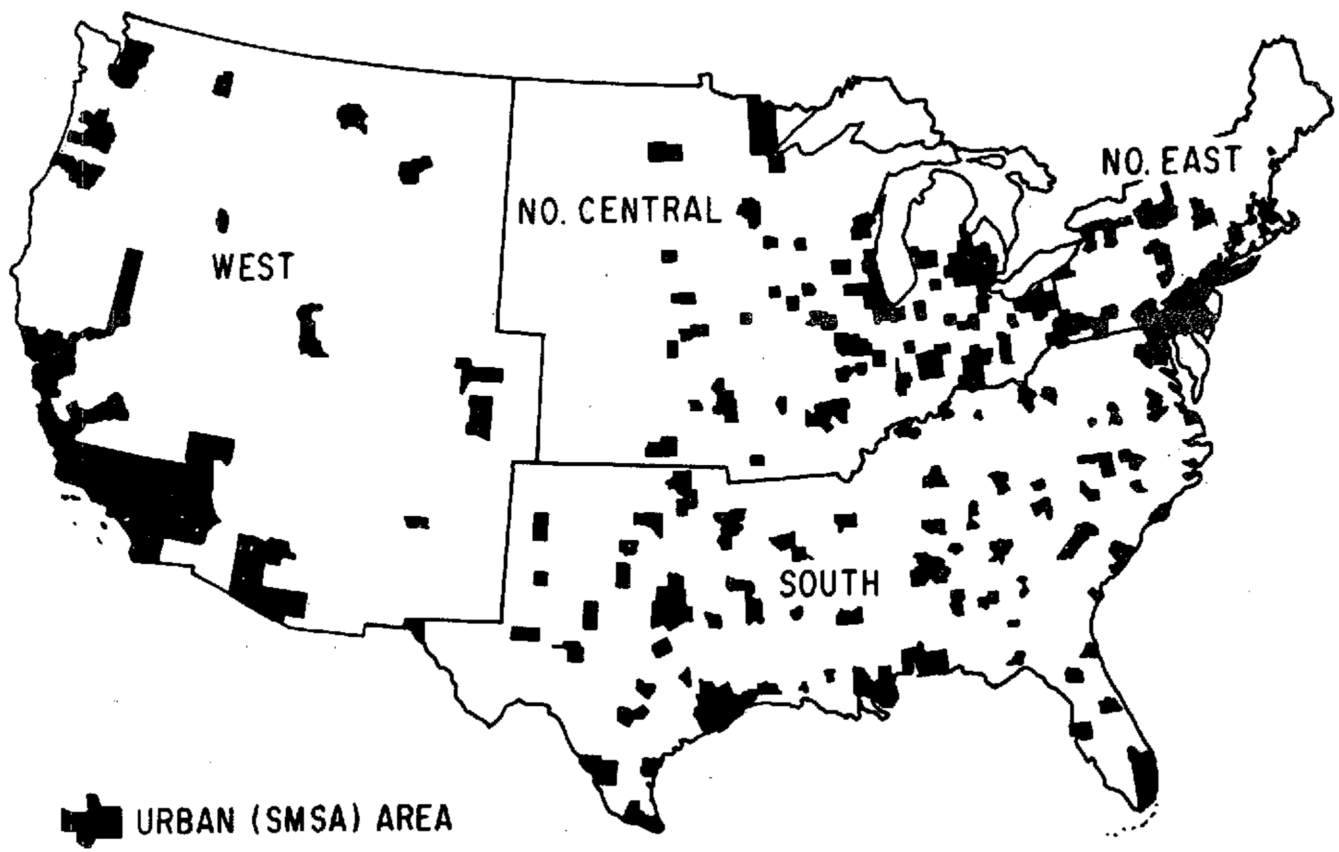

Figure 1. Urban and Rural Areas

The characteristics of both urban and rural areas will vary from one section of the United States to another. For this reason, this study examined two low-density arenas of diverse character selected from the four regions of the United States as defined by the Census Bureau:[10] West, South, Northeast and North Central.

The Bureau of Commerce divides the country into major trading areas for compiling and presenting economic and commercial statistical data.[11] Each major trading area has a major trading center and several smaller basic trading areas each with its own basic trading center. The United States had 50 major trading centers and 394 basic trading centers with the local travel following the trade routes radiating from the major trading centers. The major trading areas and centers are shown in Figure 2. The areas and travel distances pertaining to these major trading areas vary as a function of the population densities and the topography. The average and maximum trading area stage lengths were compiled for each of the four regions of the United States as shown in Figure 3. These distances allow an estimation of the relative stage lengths for low-density air service.

The air transportation hubs for the United States have developed in conformance with the long-distance travel requirements of the country. The hub definitions used by the Federal Aviation Agency/Civil Aeronautics Board are as follows:

Certified Air Carrier Hubs	Percent of Total Enplaned Passengers
Large	1 or more
Medium	0.25 to 0.99
Small	0.05 to 0.24
Non	Less than 0.05

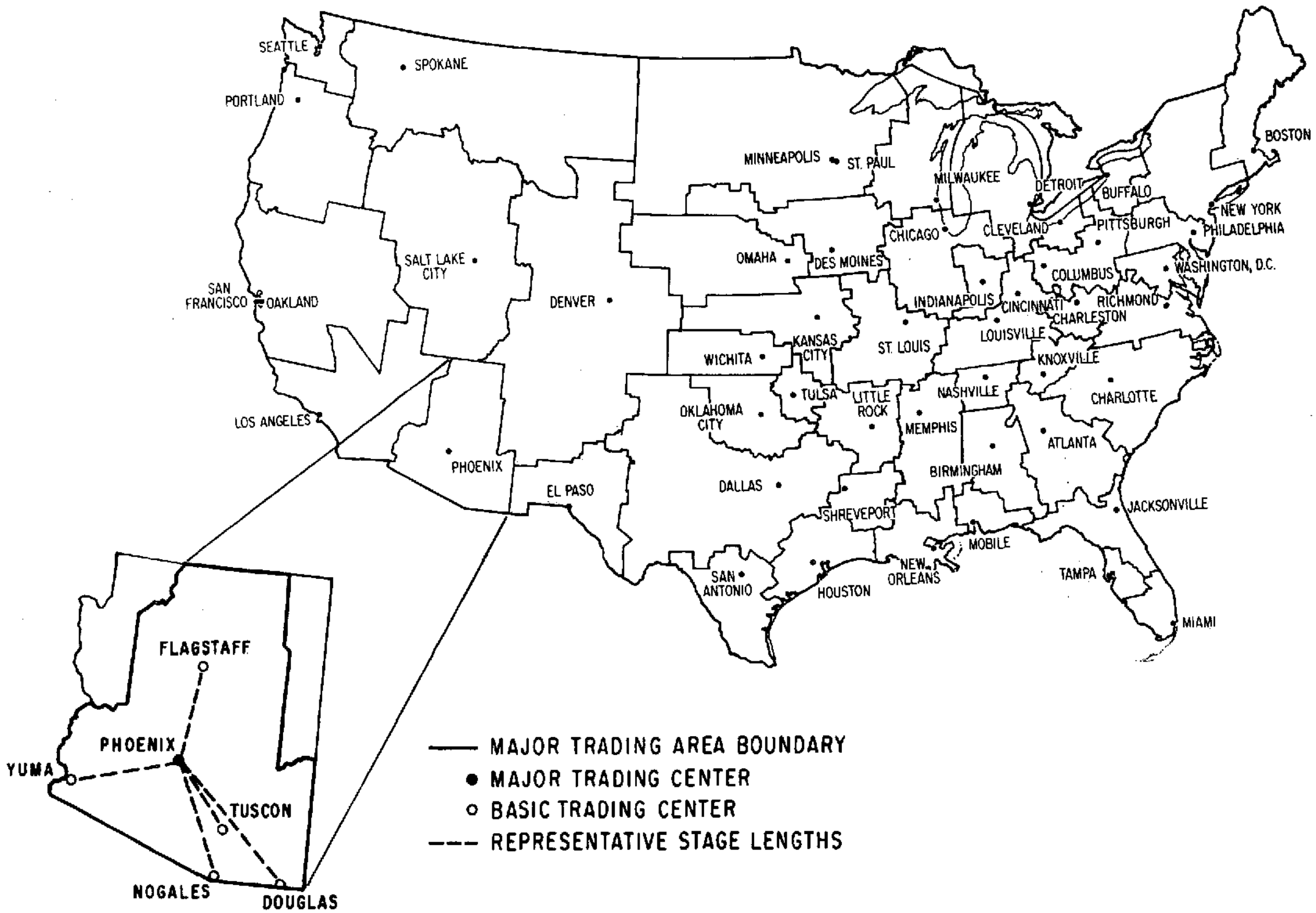

Figure 2. Major Trading Areas

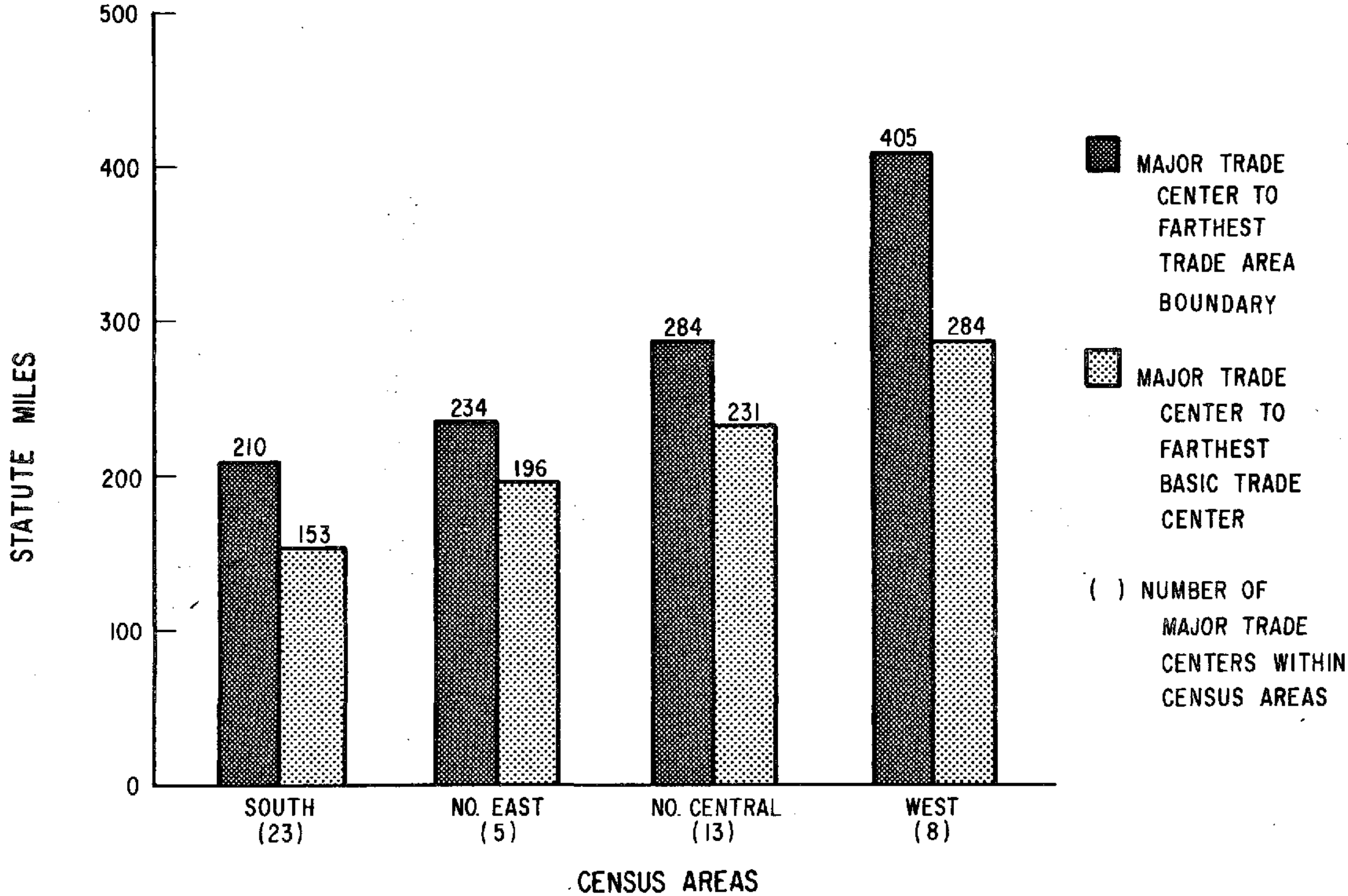

Figure 3. Average Area Stage Lengths

An analysis of the number of large, medium, and small hubs and nonhubs for each of the four regions indicated a tendency towards an equal number of large air hubs in each region. However, the number of medium and small air hubs varied from region to region (but showed a good correlation with the total population of each region). An examination of the air service provided at the hubs showed that all of the large and most of the medium air hubs were provided with good long-haul trunk service. These large and medium hubs are shown in Figure 4. Most of the small and all of the nonhubs primarily provide local short-haul service.

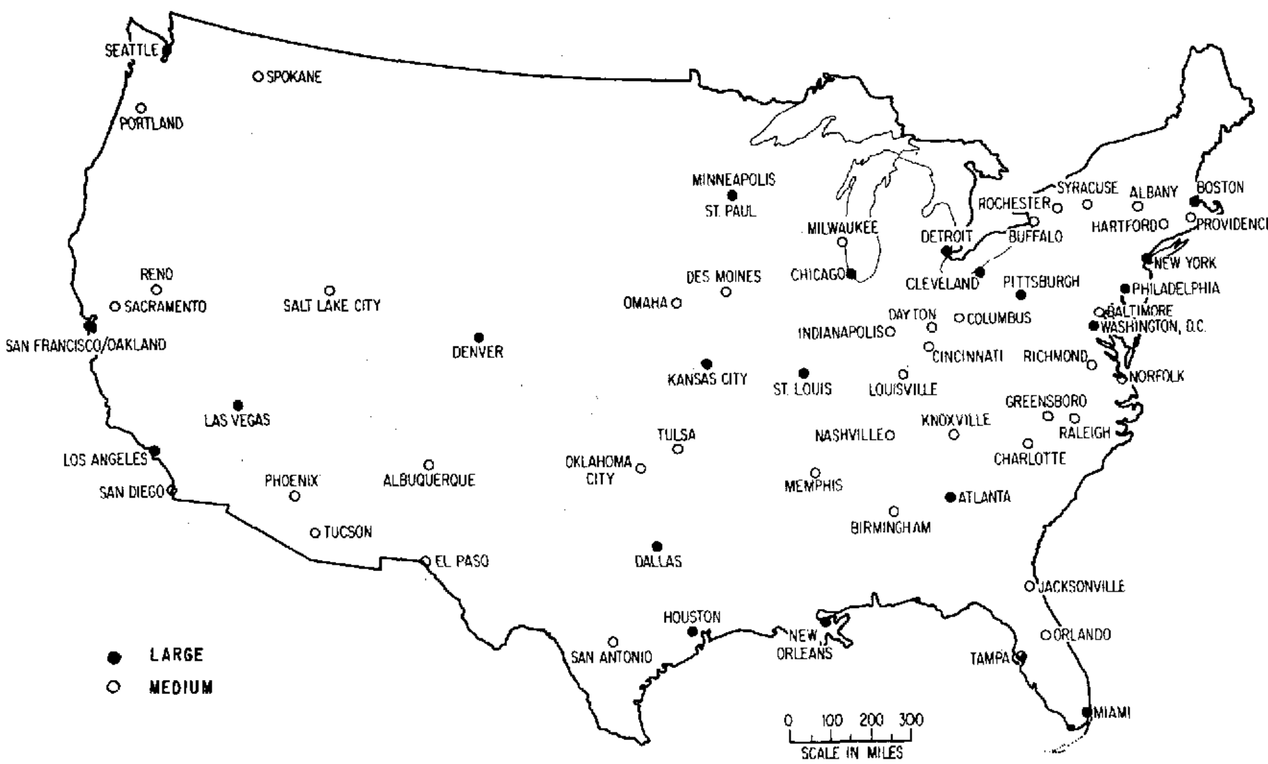

Figure 4. Major Air Hubs

The regional characteristics (population density, trading areas, air transportation hubs) are summarized as follows: the South has the largest percent of rural population follwed by the North Central, West, and Northeast regions. In terms of rural population density, the West is the least populated with eight people per square mile, the Southern and North Central regions have approximately 30 people per square mile and the Northeast has 75 people per square mile. In terms of major trading centers, the South has the largest number with the shortest travel distances involved and the West has next to the lowest number with the largest travel distances involved. A large or medium air hub is required for the long-haul air service with about an equal number available in each region. Overall, the West and South are the most representative low-density regions for further analysis.

B. LOW-DENSITY TRAVELER CHARACTERISTICS

An analysis was made of the United States travel characteristics utilizing the information available from the 1967 Census of Transportation[12] tape and the 1970 Origin and Destination Air Traffic Survey.[13] An evaluation was made of the regional travel patterns, the air traveler characteristics, the rural household propensity to travel, and the rural air travel propensity.

The regional travel patterns were examined to determine the variations in travel mode between regions and to understand the variations in travel mode between urban and rural travelers within a given region and also how urban and rural travel patterns vary from one region to another. Nationally, the automobile is the predominant travel mode comprising 85% of the total travel with air following second with 8% of the travel and all other modes capturing the remaining 6%. For rural travel alone, the automobile captures about 95% of the travelers with the air capturing 3.5%; all other modes approximate 4.5%. The larger automobile percentage for the rural regions reflects the fact that the car is currently the only means

of transportation available to a large portion of rural America. This percentage is stage length-dependent and represents the average for all stage lengths. However, as the stage length increases the air travel mode percentage increases at the expense of the other modes.

The rural region travel patterns exhibited a maximum variation of 1% between regions, indicating the problem of providing viable common carrier service to rural regions is shared throughout the country.

The air traveler characteristics were derived to show the percentage increase in the air travel mode as the traveler's trip distance increases. This data was obtained for urban-to-urban travel and rural travel (rural-to-anywhere, and urban-to-rural). The minimum distance at which this air modal split approaches zero is an indication of the minimum stage length for which viable air service can be provided. This distance will vary depending upon local conditions. Also, the air mode percentage difference between the urban and rural data is indicative of the potential for rural air passengers if improved air service can be provided.

A sort was made of the 1967 Census of Transportation[14] data tape to obtain household propensity to travel. In order to provide household traveler characteristics peculiar to low-density or rural regions, these results provide such factors as trip purposes, trip distance, traveler economic characteristics, and person trips per household on a regional basis. Some typical examples are shown in Figure 5 which indicate the propensity for taking trips by all modes of travel as a function of income, purpose of trip, trip distance, region, and trip origin and destination.

The most important point to emerge from this analysis of traveler characteristics was that no consistent pattern or trend of travel according to household income level seemed apparent. That is, excepting

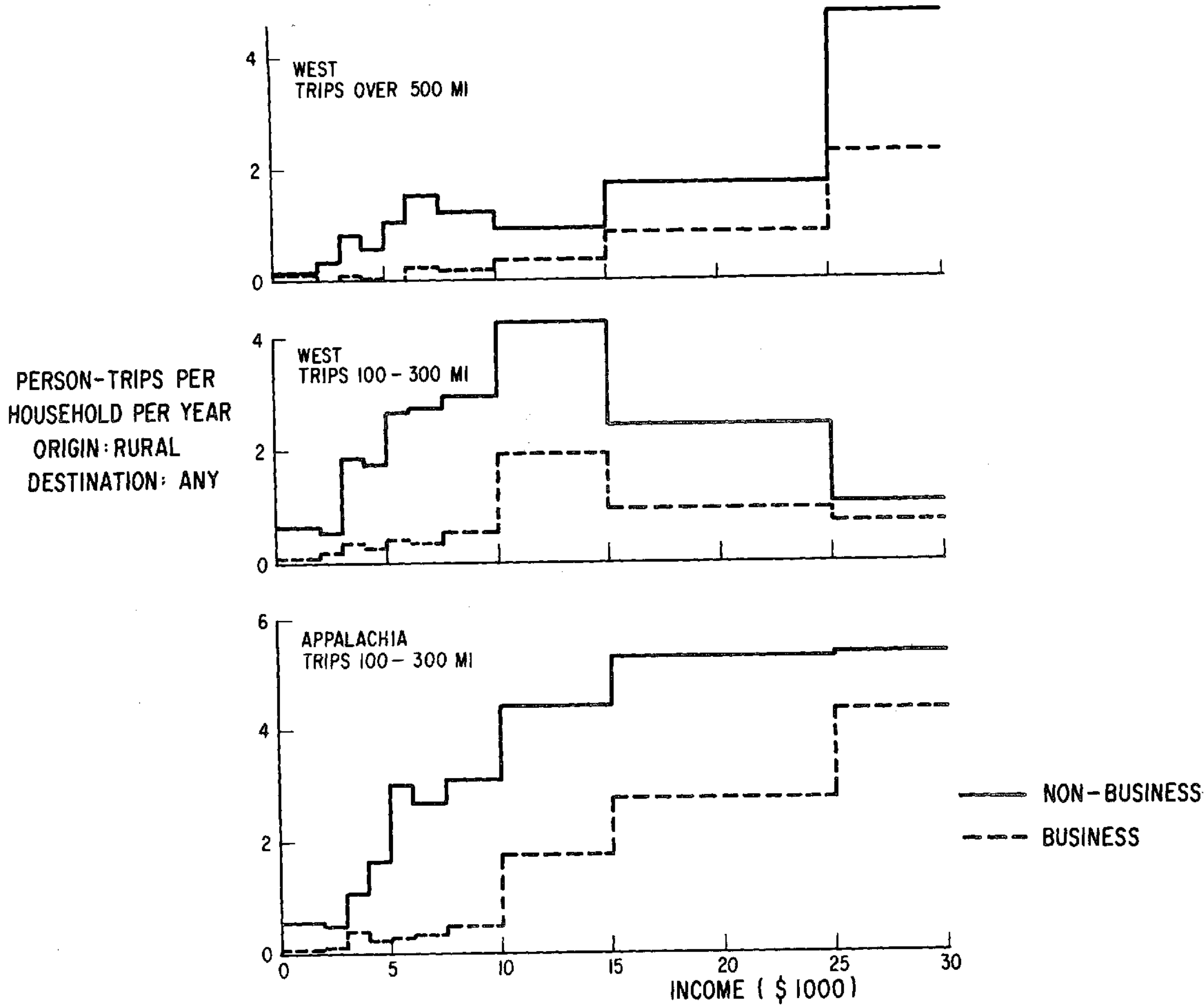

Figure 5. Propensity to Travel

the under $4,000 per year income class, there was no particular income group which consistently traveled more or less than any other for the regions examined. This simply points up the fact that each region of the country has its own peculiar traveler characteristics which should be taken into account in any analysis involving different parts of the country.

Based upon the 1970 Origin and Destination Survey of Airline Passenger Traffic[15] an examination was made of the rural air traveler data to determine (1) the percentage of onboard air travelers that are either local or connecting, and (2) the rural travel propensity as a function of population and frequency of service. A regression analysis of the low-density air traveler indicates that the low-density air demand consists of a mix of local and connecting travelers. The connecting traveler desires to connect with long-haul air trunk service which is available at all large and most medium-sized air hubs. At distances of about 100 miles from the hub, the connecting travelers comprise approximately 50% of the onboard passengers. As travel distances to the hub decrease, connecting passengers form the dominant demand; as distances increase, local travelers become dominant. The local air traveler tends to gravitate to routes radiating from the major trading center.

From this examination of air traveler data, the following conclusion is significant: to achieve an adequate load factor in a low-density region requires that both passenger sources (local and connecting) be combined; therefore, the potential low-density air transportation arena should comprise a major trading area where the major trading center is also an air hub offering good long-haul air trunk service. The boundaries of this low-density air arena would usually be the established boundaries of the major trading area; however, the boundaries could be established by the locus of points equidistant between two air hubs offering equivalent service. There are 45 potential low-density air arenas

in the United States that satisfy this criteria. In addition, there are 23 marginal arenas where the major trading center is concurrent with a small air hub or where a large or medium air hub is concurrent with the basic trading center rather than a major trading center.

C. LOW-DENSITY ROUTE AND OPERATIONS CHARACTERISTICS

A rural air service operator has some flexibility in changing or adjusting such things as routing, frequency of service, fleet size, and scheduled fare. Characteristics such as these as opposed to the more rigid intrinsic factors such as aircraft performance and cost are considered to be operational characteristics. These are discussed below.

Two routing structure concepts were considered in this study. The first concept comprised three types of nonstop air service segments as shown in Figure 6. Phoenix and Tucson, Arizona; Las Vegas, Nevada; and Charleston, West Virginia were the principal hubs which were combined with the rural towns to make up a total of 30 of the 34 nonstop city pairs (Types A & B) analyzed in detail in this study. In addition, four Type C city pairs were analyzed. The Type A city pairs are considered to have good potential, the Type B city pairs marginal potential, and the Type C city pairs little potential for viable nonstop service. The 34 city pairs are summarized in Table 1.

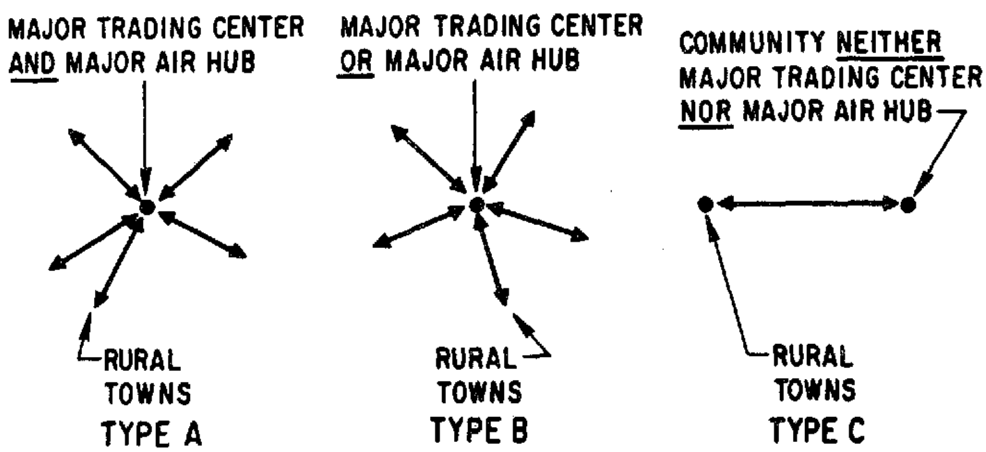

Figure 6. Nonstop Route Concept

Table 1. City Pairs Analyzed

	Arena	City Pair		Type of Nonstop Route
1.	Arizona	Phoenix	- Ajo	A
2.			- Clifton	A
3.			- Douglas	A
4.			- Flagstaff	A
5.			- Ft. Huachuca	A
6.			- Globe	A
7.			- Grand Canyon	A
8.			- Holbrook	A
9.			- Kingman	A
10.			- Lake Havasu City	A
11.			- Nogales	A
12.			- Page	A
13.			- Parker	A
14.			- Prescott	A
15.			- Safford	A
16.			- San Manuel	A
17.			- Show-Low	A
18.			- Springerville	A
19.			- Willcox	A
20.			- Winslow	A
21.		Tucson	- Ft. Huachuca	B
22.			- Douglas	B
23.		Las Vegas	- Kingman	B
24.			- Prescott	B
25.	West Virginia	Charleston	- Bluefield	B
26.			- Beckley	B
27.			- Clarksburg	B
28.			- Huntington	B
29.			- Morgantown	B
30.			- Parkersburg	B
31.		Parkersburg	- Clarksburg	C
32.			- Huntington	C
33.			- Morgantown	C
34.		Beckley	- Huntington	C

The second route structure concept considered is illustrated in Figure 7, and incorporates a "scheduled stop-on-demand" or modified

"dial-a-plane" concept. In this case, a basic or nominal service path is established between a rural town, Point A, and an air hub, Point B. A second rural town, Point C, off the nominal path, is considered for service to the air hub only when passengers request or "demand" it. Passenger traffic between the two rural towns is negligible compared with traffic to the hub.

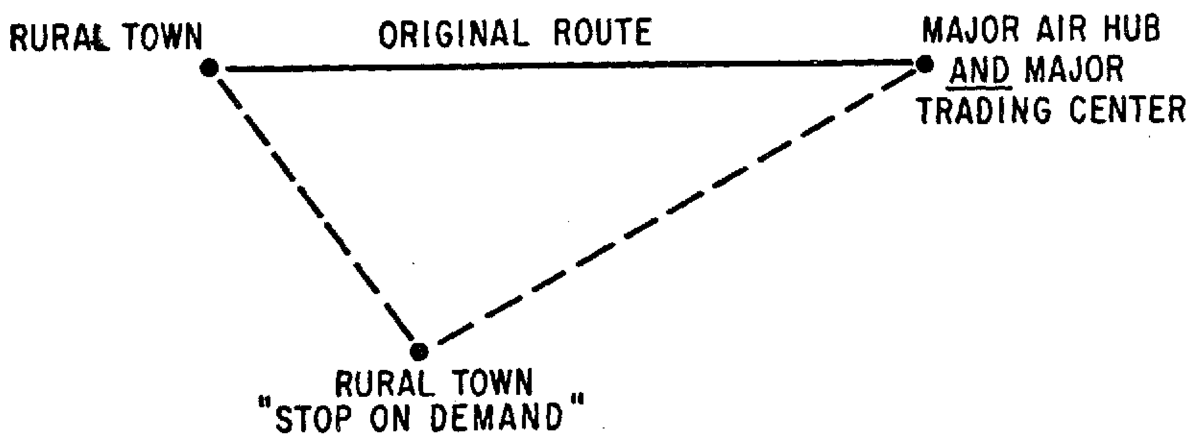

Figure 7. Scheduled "Stop-On-Demand" Route Concept

One example of this route structure was analyzed to determine the circumstances (e. g. , minimum average number of passengers required at Point C) under which total service could be made more viable. Phoenix-Ft. Huachuca was the nominal service path and Willcox, Arizona was the "stop-on-demand" rural town chosen for this example.

Scheduled fare, frequency of service, and fleet size were treated as parameters in this study. In order to reflect realistic physical

constraints, the aircraft load factor was not allowed to exceed 0.75 and the aircraft utilization was not allowed to exceed 3,000 hours per year. This was accomplished by adjusting the frequency of service and fleet size upward appropriately when required.

No data for the low-density arena was available which indicated significant variations in scheduled operations between weekends, weekdays, or holidays. For that reason, in this study air service was assumed to be provided 7 days a week with consistent schedules from day to day.

D. ARENA SELECTION AND CHARACTERIZATION

1. ARENA SELECTION

The study ground rules called for one of the two arenas to be in the area previously examined in the Western Region Study[16] and the other arena to have different characteristics. Arizona was selected as the first arena since it exhibited low-density characteristics and had a major trading area with a major trading center concurrent with a large air hub. The area of West Virginia was chosen as the second arena since it differed substantially from the first in terms of average stage length, population density, population growth, and automobile modal characteristics. It did not have a major trading center concurrent with a large or medium air hub.

2. ARENA CHARACTERIZATION

The basic requirements for arena characterization were twofold. Development of total intercity travel demand required detailed data on city population, population projections, and total daily two-way travel by all modes. Development of air travel demand required use of a modal split computer simulation program, and data inputs for use of this program involved development of city family incomes, demographic characteristics

of the larger cities (Phoenix in particular), port locations for each mode, local travel functions, and intercity modal travel characteristics of distance, time, and cost. Planned improvements in interstate highways were also obtained to allow projections of future travel times and distances by automobile.

E. DEMAND DETERMINATION

The methodology of determining demand for intercity air travel involved the following steps:

1) Combining data from all modes into a total intercity travel demand for each city pair.

2) Fitting the data with a gravity model to allow projections of total travel as a function of projected populations and ground travel distances.

3) Using the modal split simulation to develop percent travel by each mode for a nominal frequency of service and set of aircraft characteristics, fares, etc.

4) Applying the air modal split percentages to the total projected demand to obtain local air travel.

5) Determining the number of air travelers involved in connecting flights and adding these to the local air travel to obtain total air demand projections for each city pair.

1. TOTAL DEMAND

The total travel demand (all modes) was derived using a gravity model of the form:

$$T = A \times \frac{(PP)^B}{(D)^C} \qquad (1)$$

where

T = number of trips between a city pair

PP = product of the two cities' population

D = ground distance between the two cities

A, B, C = calibration constants

The calibration constants (A, B, C) were evaluated for each arena by taking six city pairs, whose populations and intercity trip demand were known, and performing a least squares fit on the data. It was further assumed that for limited changes in population with time, the calibration constants would remain constant. It is seen from the above expression that for any given city pair where the demand and population are known at a point in time t_1, projections of demand for a future time t_2 can be made by using only the population projections and the constant B, as follows:

$$T_{t_2} = \left(\frac{PP_{t_2}}{PP_{t_1}}\right)^{B} \times T_{t_1} \tag{2}$$

Use of Equation (2) thus allows calibration of the factors of travel between the two cities (e. g. , recreational factors, economic factors, and locations of universities). Equation (1) was only used when no historical data on intercity travel demand existed.

2. AIR DEMAND

As discussed previously the air demand for local travelers was obtained by multiplying the total demand for each city pair by the percentage of air modal split derived from the modal split simulations. To obtain the number of additional passengers generated by connecting flights, a regression analysis was made utilizing CAB 1970 origin and destination air passenger traffic statistics.[17] The results indicated that the percent connecting air passengers could be expressed as a function of nonstop air miles between a city pair. Separate functions were developed for both the Arizona and West Virginia arenas and used to determine the total number of connecting passengers for each city pair.

F. MODAL SPLIT ANALYSIS

1. OVERVIEW

a. The Simulation Model

Modal split analysis determines the fraction of the total intercity demand which is assigned to each intercity travel mode. The method described herein computes the modal split by generating simulated travelers, each having a set of pertinent attributes randomly selected from appropriate probability distributions. Once an individual traveler's attributes have been generated, his "cost function" for each travel mode is computed. This cost function reflects out-of-pocket cost, trip time, travel mode service frequency, and traveler preferences. When the cost functions for the alternative modes have been computed, the traveler is assigned to the mode with the minimum cost function. A valid estimate of the modal split is obtained by simulating a statistically adequate number of travelers.

Figure 8 depicts an abstraction of a typical low-density arena for which the modal split simulation is made. A major trading center or hub city is divided into a number of rectangular zones of various sizes. A much smaller rural city is represented as a point source at the center of town. Each travel mode has one or more ports in or around each city. The car mode is also considered to have ports, which normally represent points of access to the highway system between the two cities. Each port-pair of each mode for which service is provided is called a service path. Service, when provided, is characterized by its cost, trip time, and frequency (car mode is always considered to have infinite service frequency).

b. Calibration and Application

Model calibration is the process of adjusting mode preference factor distributions so that the model accurately predicts actual mode

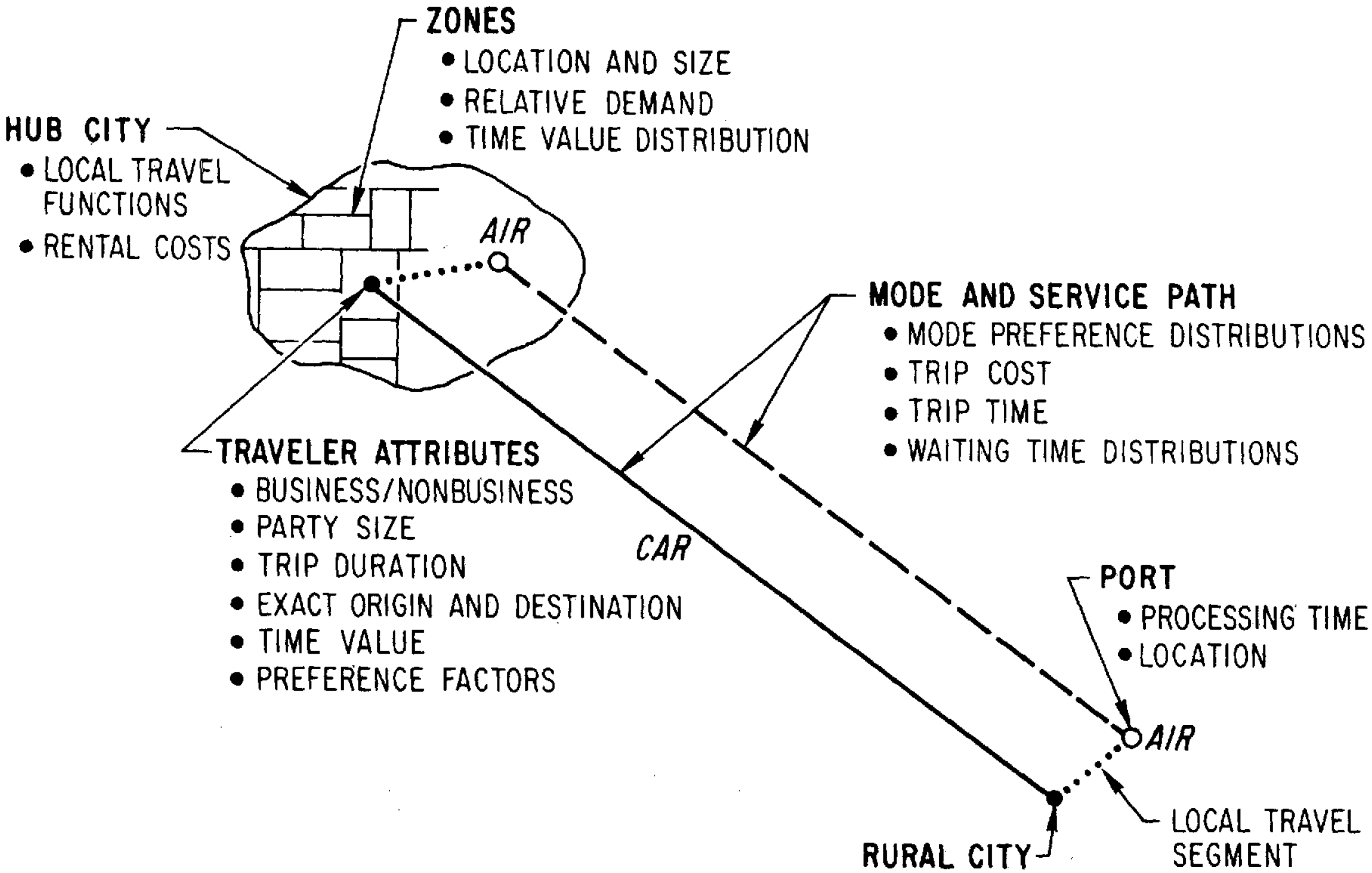

Figure 8. Typical Low-Density Modal Split Model

usage for some base year. Preference factors represent qualitative feelings a traveler might have about a mode (such as comfort or safety) and, therefore, vary over different regions of the country along with traveler attitudes and mode characteristics.

After calibrating the model for a given arena and base year, predicted air demand for the 1975 time period is obtained as a function of air fare, travel time, and service frequency. These results are used later to establish optimum operating characteristics for the proposed air service.

2. MODEL INPUTS

a. Traveler Inputs

Inputs associated with all travelers in a given arena consist of the number of simulated travelers to be generated in order to get a statistically accurate modal split, the fraction of those travelers that represents business travelers, the relative number of travelers that live in each city, the party size and trip duration distributions for both business and nonbusiness travelers, the fraction of travelers affected by frequency of service, as well as a factor which expresses the conversion of waiting time to perceived time.

The distinction between business and nonbusiness travelers is important because many of the attributes directly affecting mode choice are dependent upon whether or not the traveler is on a business trip (for example, the traveler's time value, trip duration, and party size). Party size is important because the direct costs associated with the car mode are divided by party size, while those of other modes are not. Trip duration is important because certain costs (for example, the parking cost at a port) are dependent upon the length of the trip. The trip duration distributions were found to be inherently lognormal, and so are represented by two parameters related to the median and standard deviation of a lognormal distribution.

The fraction of travelers of a given type (business or nonbusiness) affected by frequency of service represents those who have strong schedule preferences; much of their waiting time at either end of a flight or trip is wasted. Conversely, the fraction not affected by service frequency represents those flexible travelers who would not be appreciably inconvenienced even if a mode had only a few departures per day. For those travelers who are affected by service frequency, waiting times are randomly drawn from prespecified uniform distributions. These waiting times are then converted to their equivalent perceived times. Waiting time may be perceived to be worse than traveling time if the waiting is done at a port or station. On the other hand, if waiting is done at home or at the office, this may be time effectively spent and the delay would not consist of totally wasted time.

b. City Inputs

For each city, local travel tables provide cost and time relationships as a function of distance for both the private car and a composite local transportation mode. These tables permit the cost and time associated with the door-to-port (origin city) and port-to-door (destination city) portions of trips to be computed based on the distance to be traveled. The tables enable each simulated traveler to make a tradeoff between driving his car and parking at the port (for his trip duration) and the composite local transportation mode (which may be a weighted average of being driven and dropped off by a relative, or taking a taxi, local bus, etc.). Travelers who use the car for their port-to-port mode must use the car tables for local travel in each city. Travelers using noncar modes must use local transportation in the destination city, but may choose the most cost effective door-to-port mode in the origin city.

Tables of transportation rental cost versus trip duration are also provided. Travelers who take a noncar mode must incur this rental cost as a "penalty" for not having a car when away from home. However, this cost is divided by the traveler's party size.

c. Zone Inputs

The inputs associated with each rectangular zone of the hub city are the coordinates of the corners of the zone, the relative travel demand (the number of travelers emanating from or arriving at that zone relative to other zones), and the lognormal time value distributions for business and nonbusiness travelers. Only the time value distributions are given for the rural city since all demand is assumed to be located at one point.

Time value is the hourly rate the traveler associates with the time spent on his trip, and is generally considered to be different when he is traveling on business rather than nonbusiness purposes. Time value is used to convert total trip time to equivalent dollar cost.

d. Mode Inputs

Each travel mode has an associated lognormal preference factor distribution. Preference factors for the various modes are intended to represent all of the noneconomic factors affecting mode choice; that is, all of the factors which cannot be expressed in units of cost or time. Since they represent the intangibles, the preference factors are the calibration parameters of the simulation model. They are the quantities that are adjusted to achieve consistency between model predictions and actual mode-use surveys in arenas for which survey data exists. In the simulation, the intercity portion of a traveler's cost function for each mode is divided by his preference factor for that mode (as drawn from the appropriate distribution). Thus a preference factor of less than one for a given mode indicates that the traveler views that mode with disfavor, whereas a factor of greater than one indicates a preference for the mode. Preference factors, therefore, represent the degree to which a traveler will go against pure economics in choosing a travel mode.

e. Port Inputs

Each travel mode may have one or more ports in each city. Each port is characterized by its location, processing time, parking time, and a

table of parking cost versus trip duration (the length of time in days that the traveler will be away from his resident city). The processing time is the time spent from arrival at the entrance to the port until the intercity portion of the trip begins. This time might typically include baggage checking, intraport movement, and ticketing, but does not include waiting which is treated separately. The parking time is the additional time required to park a car and walk from the parking lot to the port entrance. This time is added if the traveler elects to drive his car to the port and park it for the trip duration. The parking cost table is used to establish the cost he incurs.

f. Service Path Inputs

The inputs associated with each service path are those required to describe the service provided between that pair of ports: out-of-pocket cost, trip time, and a waiting time distribution. For public transportation modes, the out-of-pocket cost is the fare and the trip time is the scheduled time (which may include an increment for predictable or usual delay). Uniform waiting time distributions are determined from the scheduled departure times and a diurnal distribution of desired traveler departure times.

For the car mode, cost represents nominal operating costs over the designated trip length and time is determined from road conditions and highway distances. A traveler's car is always assumed to be available, so waiting time is zero.

The method of determining the uniform waiting time distributions for the noncar modes is tied to the number of departures or service frequency. If there are many uniformly spaced departures per day, one can assume that the distribution of desired traveler departure times is uniform between any two consecutive departures, independent of the departure times. In this case the mean of the uniform waiting time distribution can be taken to

be one-half the time between departures. For example, if there are departures every hour, the average traveler will have to wait one-half hour from his desired departure time. In this case one would input a uniform waiting time distribution between zero and one hour.

However, if there are only a few departures per day, the departure times become very critical and one must then take into account the diurnal distribution of desired traveler departure times. In a low-density short-haul arena, most travelers want to go to the hub city in the morning and return in the late afternoon. Therefore, two departures a day at good times (e. g., 8:00 AM, 5:00 PM) would satisfy most of these travelers. In this case the mean waiting time of all travelers throughout the day would be about two hours. On the other hand, if the two departures per day were at less favorable times (e. g., 10:00 AM, 3:00 PM) many travelers would have to wait longer for the morning departure and be forced to leave early in the afternoon (or stay overnight for the next morning's departure). This case would be more accurately modeled with a mean waiting time of three hours.

3. MODAL SPLIT DETERMINATION

a. Generation of Traveler Attributes

The attributes of each simulated traveler are generated by random draws from the input probability distributions described in the preceding sections. Correlations between attributes are explicitly represented in that the determination of a given attribute may define the distributions from which other attributes are drawn.

The sequence used to generate a complete set of attributes for a simulated traveler is as follows. First, a draw is made based on the number of travelers who live in each city to determine the traveler's resident city. This is the city in which his trip is assumed to originate.

Next, a draw is made based on the specified fraction of travelers that are business travelers to determine the traveler's trip purpose. Based on the outcome, draws are made from the appropriate distributions to determine the traveler's origin city zone, trip duration, party size, preference factors for each of the alternative modes, and destination city zone. His time value is drawn from the distribution associated with his origin zone. Exact origin and destination door coordinates are drawn uniformly from within the origin and destination zones. A determination of whether or not the traveler is affected by service frequency is made by drawing from the appropriate two-valued distribution representing the fraction of business or nonbusiness travelers affected. If he is found to be affected, his waiting times for all the alternative service paths are computed by drawing from uniform waiting time distributions.

b. Cost Function Computations and Mode Choice

Once the attributes of a simulated traveler have been generated, his cost function for every service path is computed. The cost function for a given service path consists of three components: the origin door-to-port portion of the trip, the port-to-port portion, and the destination port-to-door portion. For each component the pertinent costs and times are summed separately, and the total time is converted to equivalent cost by multiplying it by the traveler's time value. The port-to-port portion of the cost function (cost plus time multiplied by time value) is divided by the traveler's preference factor for the mode under consideration. All costs associated with the use of a car (i. e., for the entire trip, to drive to a port and park, or the destination rental charge), are divided by the traveler's party size. For public intercity modes, a tradeoff is made between driving to the origin port and parking for the trip duration and taking the composite local transportation mode to the port; the traveler is presumed to follow the course of action with the minimum cost function.

Local travel (door-to-port and port-to-door) is presumed to take place along orthogonal north-south and east-west lines (or any other designated orthogonal compass directions for that matter) and local travel distances are computed accordingly. Costs and times are determined from these distances using the local input tables.

After all cost function computations have been made, the simulated traveler is assigned to that mode and service path which has the smallest cost function.

c. <u>Outputs</u>

The outputs of the modal split simulation program consist of optional output during simulation, and a standard set of outputs at the conclusion of a simulation. During simulation, "traveler's records" may be printed for every nth traveler (where n is specified). A traveler's record consists of all the known facts about a given traveler--all of his attributes, his assignment to a particular mode and service path, and the cost function components (all the costs and times) associated with that assignment. Traveler's records are useful for verifying that a simulation case is specified correctly and for gaining insight into why certain mode choices are made.

At the conclusion of a simulation, the number or fraction of travelers assigned to each service path of each travel mode is provided, along with the totals by city ports and travel modes.

4. CALIBRATION

a. Methodology

As explained in Section II. F. 2, one of the inputs to the modal split simulation consists of a lognormal preference factor distribution for each travel mode. These distributions effectively serve to calibrate traveler preferences for the specific trips, modes, and arenas being modeled.

Preference factors take into account qualitative aspects of a traveler's decision which are not reflected in a pure cost-time tradeoff. A traveler might prefer the air mode because of the associated prestige but dislike it due to safety considerations, while the car may be favored in scenic environments but disfavored under bad driving conditions.

The deviation parameter of the lognormal preference factor distribution is determined for each mode based upon the estimated variation of traveler attitudes towards that mode. The purpose of the calibration procedure is to determine the distribution medians for each mode. In order to obtain a unique set of preference medians for each calibration exercise, the median of the car preference factor distribution is always set equal to 1.0.

Mode use data for representative city pairs for some base year is needed to determine noncar preference factor distributions. This data is used to undertake an iterative procedure to find preference factor distributions which produce modal split results corresponding to the actual base year modal split data. These distributions will then be used directly for the 1975 modal split runs under the assumption that traveler attitudes and preferences do not change significantly in the interim.

Calibration and predictive modal split analysis based on the modal split simulation model will be applied only to local travelers whose origin and final destination are both within the modeled arena. However, there is another significant group of air travelers, called connecting travelers, whose trip to or from the hub city is only a small leg on a longer trip. These travelers do not typically behave like the local traveler since they have different attributes and requirements. Furthermore, it is very difficult to get enough data on these travelers to run a separate calibration and analysis. Therefore, these travelers will be modeled using a regression analysis after the number of local air travelers has been determined.

b. Arizona

In Arizona, as in most low-density arenas, the car is the predominant travel mode, typically accounting for 95 to 99 percent of all travel. When air service is available it accounts for the remaining travel. Bus and rail play minor roles and are rapidly diminishing on the rural scene. For these reasons, only car and air modes were modeled.

Two city pairs, Phoenix-Kingman and Phoenix-Douglas, were chosen for calibration. Both these city pairs had air service for the base year of 1970, and were representative of low-density city pairs capable of supporting air service. Table 2 represents some of the calibration data for these city pairs.

Separate calibration exercises for each of these city pairs resulted in air preference factor medians of 0.68 for Phoenix-Douglas and 0.66 for Phoenix-Kingman. In view of this exceptionally good agreement, an intermediate value of 0.67 was adopted for Arizona air travelers.

Table 2. Calibration Data for Arizona. Demand is for Base Year 1970. Income Expressed in 1969 Dollars.

City Pair	Rural City Median Traveler Income ($)	Car Distance	2-Way Daily Person Trips	Air Modal Split (%)
Phoenix-Douglas	8815	242	170	2.94
Phoenix-Kingman	7157	188	321	1.81

c. West Virginia

The process of calibrating air travel preferences for West Virginia was complicated by the fact that there was a lack of good automobile travel data for a recent base year. Data for the base year 1965 was available from

another study,[18] but analysis indicated either that the data was in error or that special circumstances (such as extermely low car ownership) existed then that do not exist now.

Furthermore, even if this data was correct, it is unlikely that preference fact ors would remain constant in West Virginia from 1965 to 1975. In particular, preference for the car is probably changing due to the substantial upgrading of roads. Trips which took eight hours over winding and often hazardous mountain roads are predicted to take only two hours over new interstate highways. Therefore, it is likely that car preference will change after adjusting for the time savings.

In light of these circumstances, it was felt that the Arizona air preference factor median would be a better estimate of the 1975 West Virginia air preference factor median than that obtained in any other manner. The interstate highway system should be completed in West Virginia by 1975 so that car speeds between major cities will be very much like what they are in Arizona today. Likewise projected air service would also be of the same quality in both these arenas.

5. APPLICATIONS

The modal split model was used to predict air modal split for the 1975 time period as a function of the following air variables: fare, travel time, and service frequency. The basic procedure was to start with a baseline set of values for each city pair and then to perturb these values one at a time to produce sensitivity curves for each air variable. All other inputs remained fixed during these runs.

The baseline values for fare and trip time for all Arizona and West Virginia city pairs are documented in Section III. B. Sensitivity curves

showing air modal split as a function of fare were obtained from a run using the baseline fare and from runs which perturbed the baseline fare $\pm$ 20%. Other air service variables remained fixed at their baseline values during the fare sensitivity runs. Similarly time sensitivity curves were produced by perturbing travel time -25% and + 40% around the baseline value. Baseline travel times reflected nonstop service at nominal speeds. Time increases could typically be of greater magnitude than decreases since increases may be due to lower speeds and/or intermediate stops, whereas decreases are due only to higher speeds.

The baseline value for service frequency was the same for all city pairs and corresponded to a mean traveler waiting time of two hours. This typically corresponds to a schedule with two departures per day at good times (e. g. , 8:00 AM, 5:00 PM). For frequency sensitivity curves, two additional mean waiting times were used. A mean waiting time of three hours was used to model a schedule with two flights a day at inferior times (e. g. , 10:00 AM, 3:00 PM), while a mean waiting time of one hour was used to model a schedule with four flights at good times (e. g. , 8:00 AM, 11:00 AM, 2:00 PM, 5:00 PM). Fare and travel time remained at their baseline values throughout these sensitivity runs.

The results of this modal split analysis consist of three sensitivity curves (corresponding to independent changes in fare, travel time, or service frequency) for each city pair in each arena. Each curve expresses the percent of total demand which would use the air mode as a function of the sensitivity variable. These curves along with projected city pair demand defined in Section II. E will be used to optimize the short-haul air system in each arena. Section II.I details this optimization analysis.

G. AIRCRAFT AND EQUIPMENT SELECTION

In order to select the optimum aircraft for operations in the low-density regions of the United States, the following items were considered:

- Capacity
- Scheduled air carrier regulations
- Commuter aircraft
- Operating performance
- Cost

The initial aircraft capacity determination was based on the existing air demand for rural areas utilizing the 1969 Civil Aeronautics Board O & D Traffic Survey.[19] An analysis was made of the travel propensity by region, frequency of departure, and population. Figure 9 shows the travel propensity for the southern and western portions of the country. An examination of the figure shows how the travel propensity can vary between regions, within a region, and with frequency of departure.

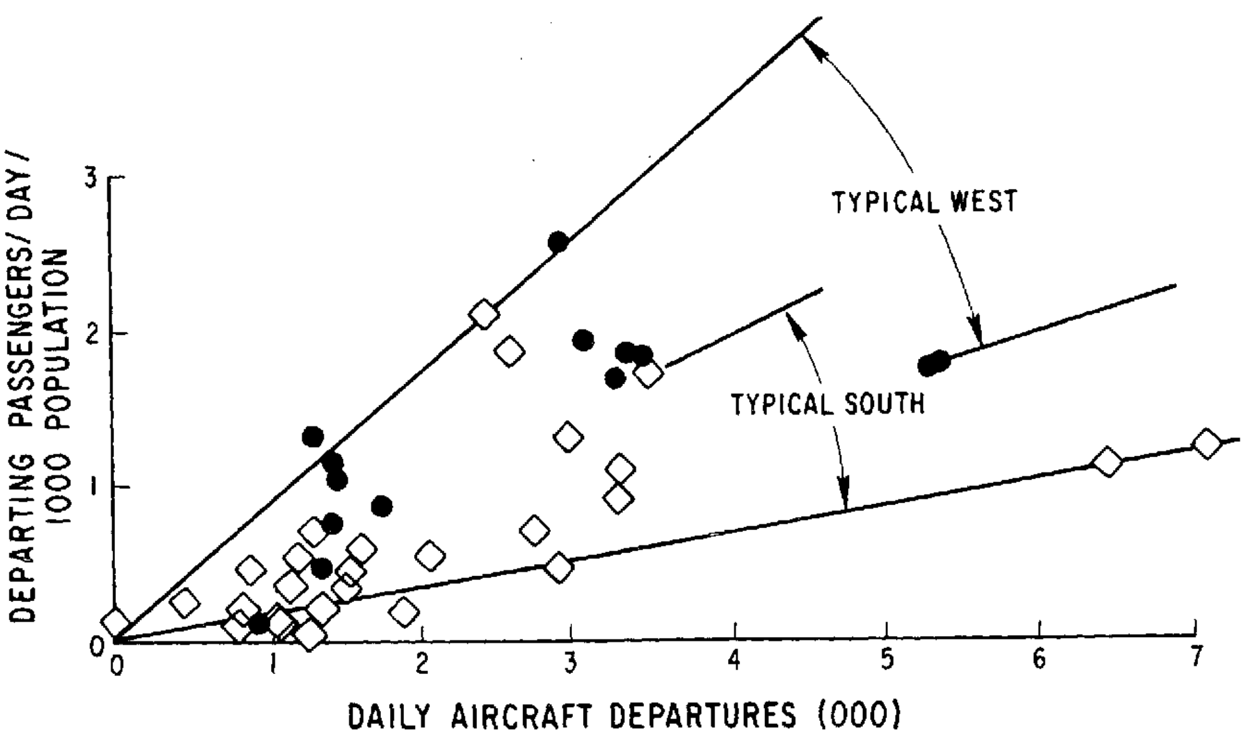

Figure 9. Travel Propensity

Figure 10 is a plot of community population related to potential aircraft capacity needs. The figure was compiled assuming four departures per day, seven days a week, and one and one-half departing passengers per day per thousand population (using the maximum air demand data from Figure 9). By entering the curve with the community population desiring air service and going across to an assumed aircraft load factor, one is able to estimate the required aircraft capacity. This allows one to estimate the aircraft capacities required to serve communities in a given rural market.

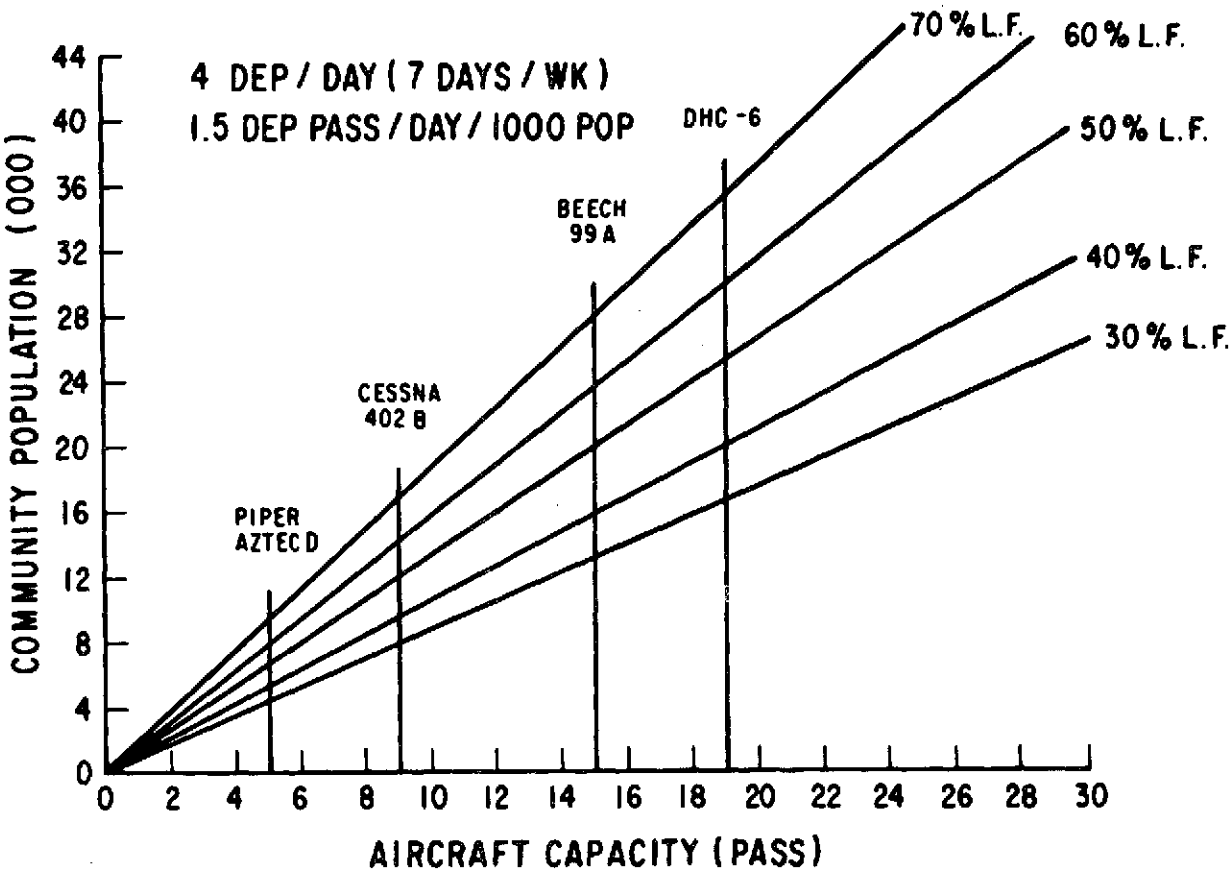

Figure 10. Required Aircraft Capacity

The current scheduled air carrier regulations increase in scope and complexity with the size of the aircraft specified. The regulations that must be considered are Economic Regulations (CAB Part 298),[20] Aircraft Certification (FAA Part 23 or Part 25),[21] Air Carrier Regulations (FAA Part 135 or Part 121),[22] and Financing Regulations (Public Laws 85-307, 87-820, 89-670 and 90-568).[23] Figure 11 emphasizes the burden associated with these regulations with augmented aircraft capacity.

Another selection consideration was the aircraft initial investment and operating cost. Three sources of cost information were utilized. The first was the manufacturer's data, the second was commuter airline operating data, and the third was the impact of the scheduled air carrier regulations as discussed in the previous paragraph. (A more complete discussion of costs is treated under Economic Analysis, Section II-H.)

A survey was made of the aircraft operated in 1969 by the commuter air carriers in the United States, and tabulation of the results is shown in Table 3. From these available aircraft, five aircraft were selected for evaluation in the low-density arenas. The selection covered a range of aircraft with capacities from 5 through 19 passenger seats, the highest cruise speeds, and takeoff and landing capabilities compatible with most of the runways encountered in the rural markets.

The five aircraft selected were the Piper Aztec Turbo E, the Cessna 402B, the Beechcraft 99A, the Twin Otter DHC-6, and the Swearingen Metro.

The variation of block time as function of trip distance is shown in Figure 12 for the selected aircraft. An average cruise altitude of 5000 feet was selected after surveying the airport and terrain characteristics in the Arizona and West Virginia arenas.

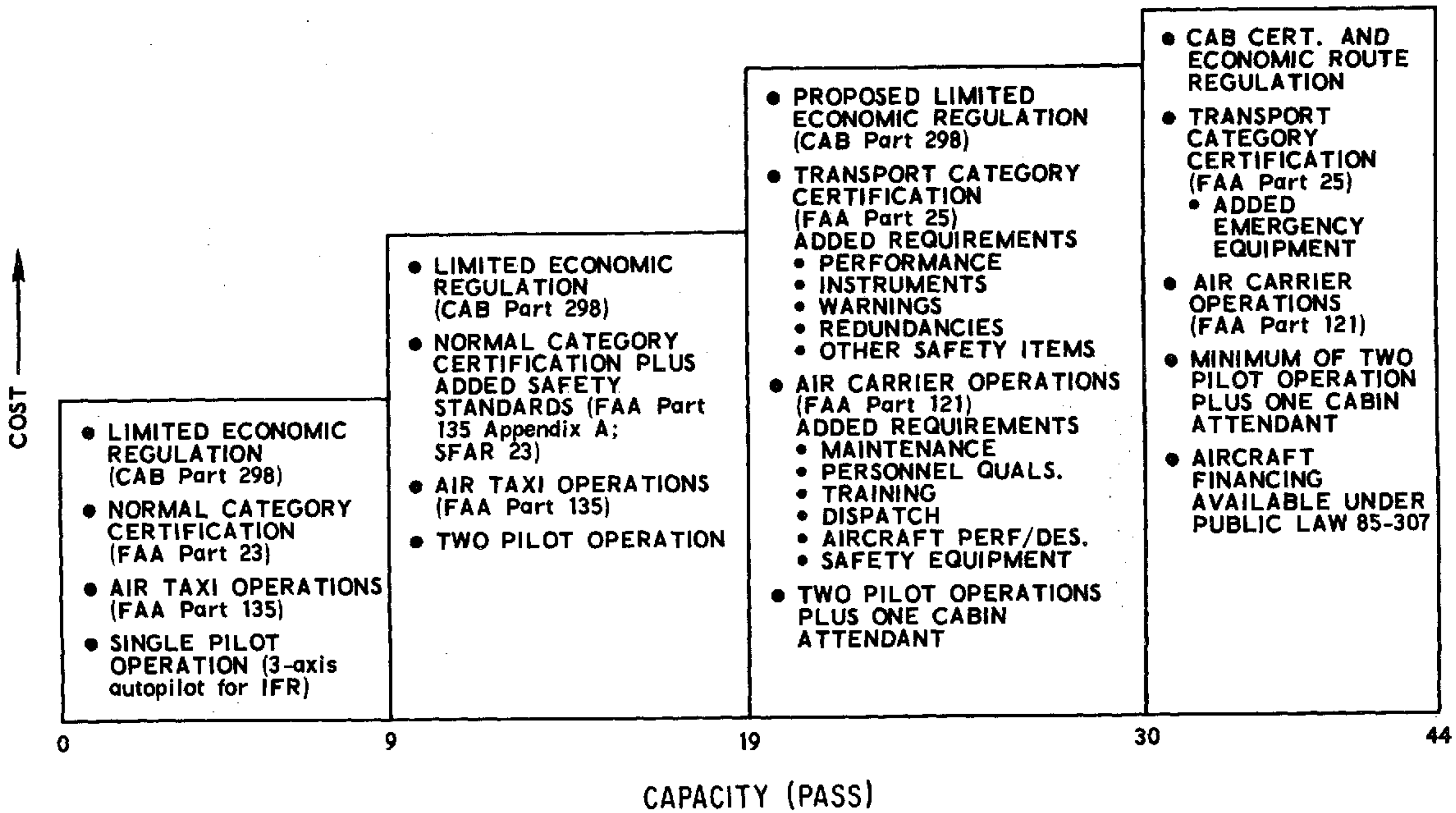

Figure 11. Impact of Air Carrier Regulations on Cost

Table 3. Principal Commuter Aircraft

Aircraft	No. (1) Operated	Cost(2) ($000)	Operating(6) Cost ($/hr)	Capacity (Passenger Seats)	Range(3) (Mi)	Speed(3) (MPH)	Field(4) Length (ft)	Minimum(5) Flight Crew
Piper Aztec	99							
Basic		103	N/A	5	882	208	2220	1-2 (7)
Turbocharged		113	41	5	657	224	2220	1-2 (7)
Piper Navajo	28							
Basic		139	N/A	5-8	224	213	2020	1-2 (7)
Turbocharged E		149	N/A	5-8	264	247	2120	1-2 (7)
Pressurized		230	N/A	5-7	524	266	2960	1-2 (7)
Beech 18	145	43-63	85	5-8	590	212	1760	1-2 (7)
Cessna 401/402	46							
Basic 402B		150	48	9	212	218	1420	1-2 (7)
Turbocharged 401		141	N/A	5-7	504	240	2220	1-2 (7)
BN-2 Islander	11							
Basic		115	N/A	9	378	160	1090	1-2 (7)
Turbocharged		124	N/A	9	492	184	970	1-2 (7)
Beech 99/99A	97	455	108	15	531	254	3900	2
DHC-6	77	550	96	19	191	192	1200	2
Swearingen Metro	0	595	129	10-19	186	305	3880	2

(1) 1969 Commuter Air Carriers only
(2) 1970 prices, including minimum avionics and optional equipment
(3) Maximum payload, cruise power, 45-minute reserve
(4) Takeoff over 50 feet
(5) FAR Part 135
(6) @3000 hr /yr utilization, with maximum avionics and optional equipment
(7) 2 required for Cat I IFR if no 3-axis autopilot
N/A - Not Available

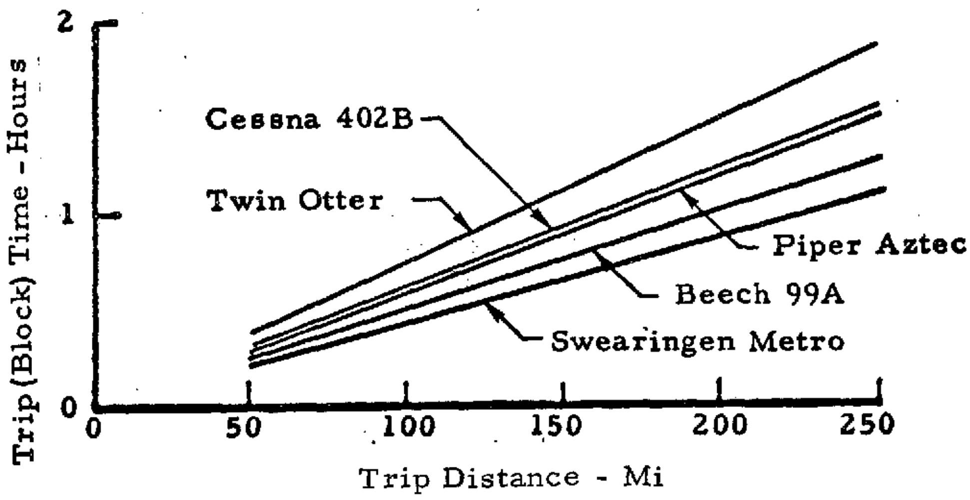

Figure 12. Block Time vs Trip Distance

H. ECONOMIC ANALYSIS

An economic analysis of low-density commuter air carrier operations was conducted to assess the viability of new air transportation operating concepts and to identify the necessary system design characteristics that comprise a viable system. Economic analysis was also used to assess the cost benefits of changes in performance such as block speed.

To be economically viable a low-density air transportation system must meet a public need as well as offer economic benefits to the traveling public, aircraft manufacturers, airlines, airport authorities, and federal, state, and local governments. However, emphasis was placed on developing aircraft and operational concepts that are viable to airlines.

Direct operating costs of various sized piston and turboprop aircraft were developed consistent with manufacturer estimates and commuter airline experience. Indirect operating costs were developed based on a study of commuter air carrier operating costs. It should be noted that there is no standard accounting system or industry method for estimating either the direct or indirect operating costs of small aircraft.

Low-density air carriers were found to have unique operational and economic characteristics. All were small with respect to number of aircraft operated, fares and operating costs per mile were high, and earnings and the ability to finance new aircraft were low. While these carriers could serve such markets at substantially lower operating costs than the larger local service carriers, the operating cost efficiency of the type of aircraft operated and the airline support operations necessary result in fare levels higher than those of certificated carriers.

A comparison of airline fares of low-density commuter air carriers versus CAB certificated carriers for stage lengths up to 340 miles is shown in Figure 13. Low-density commuter air carrier fare levels can be seen to be substantially higher particularly at the 100-160 mile stage length typical of most routes.

Some of the commuter air carriers that serve high-density markets have fare levels identical to that of the CAB certificated carriers. In many instances this reflects the assumption of prior CAB certificated routes and fares. For the purposes of this comparison such fare levels have not been included.

I. DEMAND MATCHING, ECONOMICS, AND OPTIMIZATION ANALYSIS

Viable air service is possible if the right number of air travelers are willing to pay the fare required for the airline to break even or, better yet, to provide a fair return on investment to the owners or backers. If the required breakeven fare is too high, travelers will choose other modes of travel and the airline will lose that source of revenue. The search for a balance between revenue from paying passengers and aircraft-route operating costs is what is meant by demand matching.

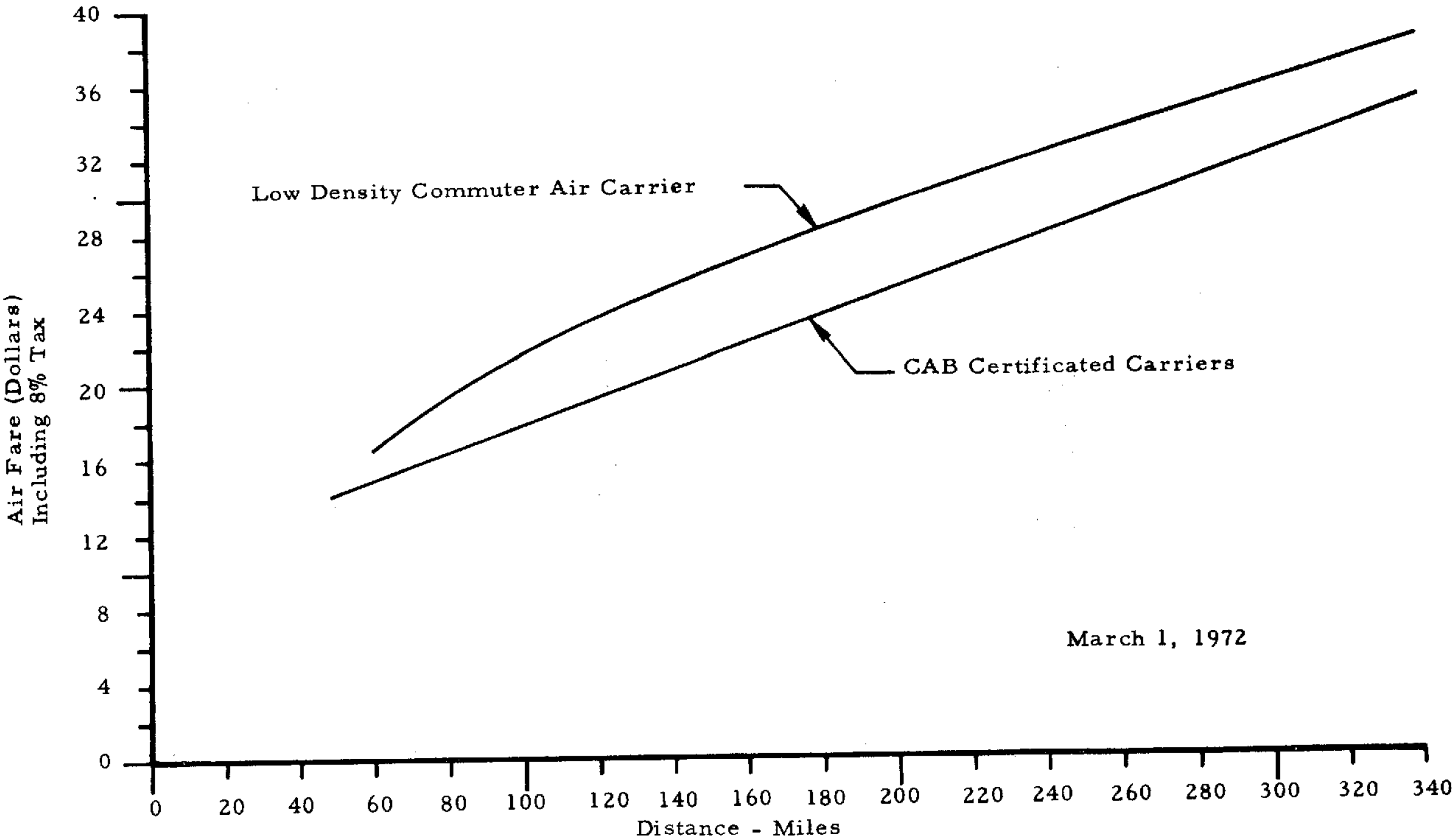

Figure 13. Comparison of Fares

Demand matching results were obtained from a computer program developed for that purpose called the Analytic Demand Matching Program. Traveler sensitivity (or elasticity) to fare, trip time, and frequency of service as a function of his income and trip purpose was determined from the Modal Split Simulation Program. In Figure 14, a functional description of the Analytic Demand Matching and Modal Split Simulation process is illustrated.

In the low-density arenas analyzed in this study the demand matching results displayed many different types of behavior. These results are shown schematically in Figure 15. The circled numbers depict the various situations that can be encountered. The optimum demand match is considered to be the relatively high demand case, shown as 1, in which breakeven (or fair return on investment) conditions exist. It should be emphasized that this situation is a goal to be strived for and not necessarily achievable. Note that situation 2, which is also a breakeven case, is less desirable because it serves a much smaller number of passengers.

The forces at work in the demand matching process very often run counter to intuition. In one case, shown as 3, the rural airline operator who raises his fares in order to offset operating losses may by that same step cause himself to lose even more money. In another case, depicted by 4, an operator in a different arena who tries the same thing may be successful in pulling himself out of the red by that approach.

The situation shown as 5 seems at first glance to be so profitable that the air service operator couldn't ask for anything better. In actuality, cases like this are not considered to be realistic because they are vulnerable to competition which can offer more luxurious service at higher operating costs, but still at a profit. Also, situations like 5, while very profitable when considered as individual air routes, may likely comprise only one part of a larger air service route structure which also includes unprofitable single routes.

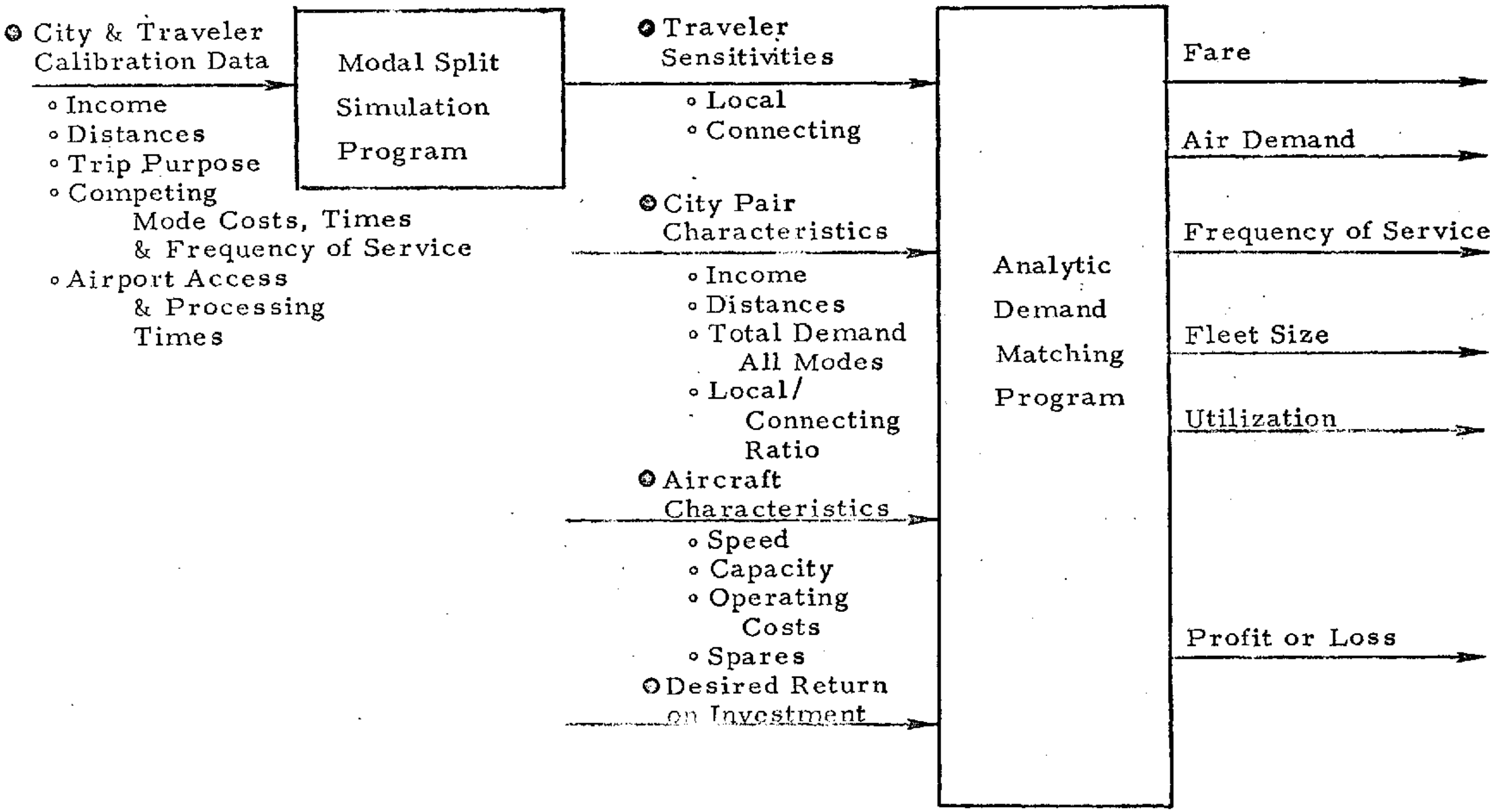

Figure 14. Modal Split and Analytic Demand Matching Program Functions

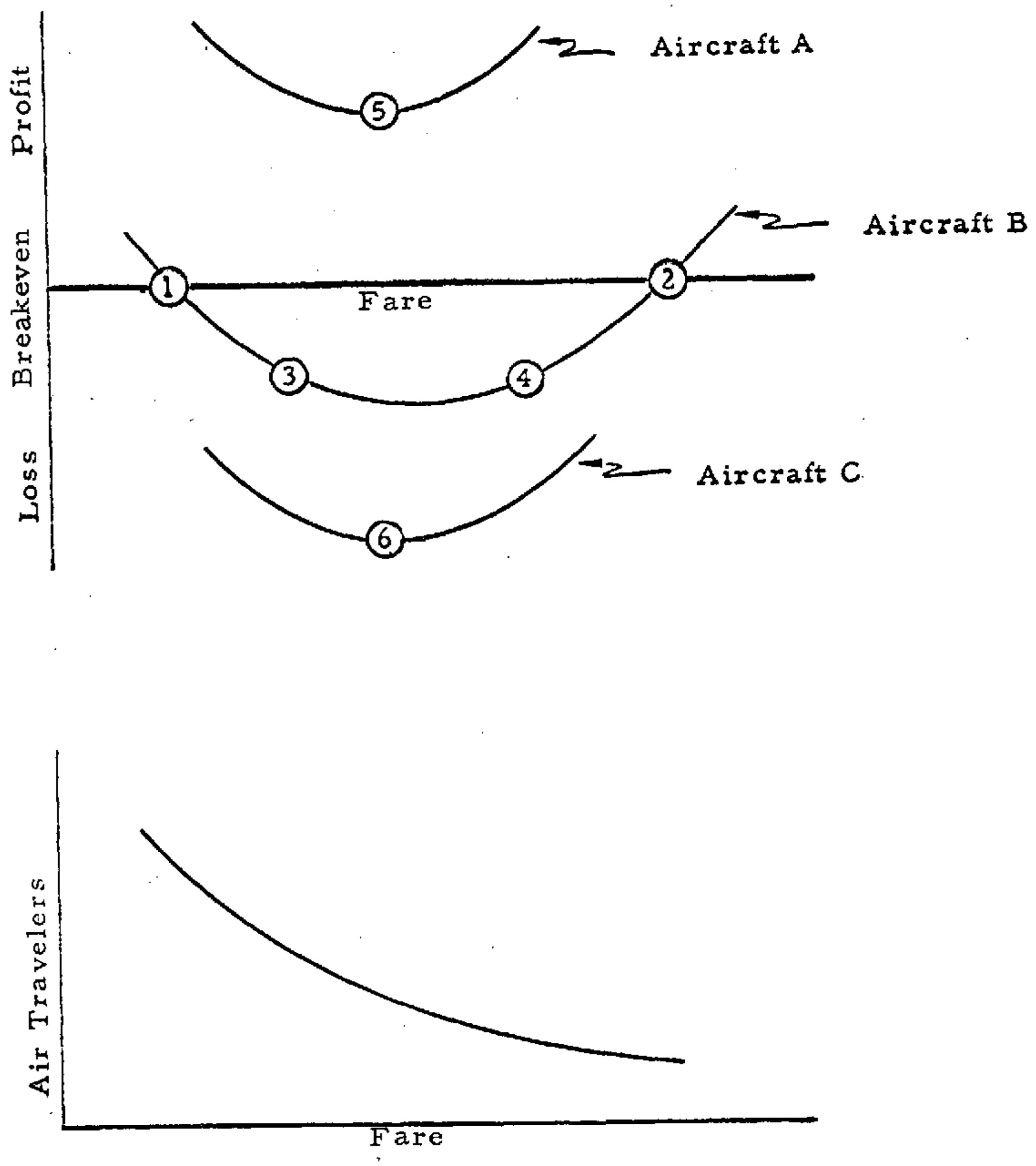

Figure 15. Typical Demand Matching Behavior

At the other extreme, shown as (6) , the situation is clearly unprofitable for that particular combination of city pair and aircraft, and no possibility for conversion to operation in the black is apparent.

The example curves shown in Figure 15 correspond to one frequency of service and a fixed fleet size. If the air demand increases to the point that the load factor for the designated aircraft is unreasonably high an increase in the frequency of service is called for. This dilutes the average load factor and changes the profit and loss picture considerably. Similarly, if the frequency of service is increased to a point that results in unrealistic aircraft operating schedules, the fleet size must be increased. Again, this changes the profit and loss picture, not always for the better.

In the sections which follow, the demand matching-profit and loss results will be shown in much the same manner as Figure 15. When a change in frequency of service or fleet size is made that change is reflected as a break in the curves. Sometimes these breaks increase profits, sometimes not. In any case, the low-density arena, unlike high-density operations, is such that the addition of only one round trip per day to the air service schedule, or the addition of only one aircraft to the fleet size can substantially affect the viability of the operation.

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III. ANALYSIS

A. POTENTIAL LOW-DENSITY ARENAS

1. ARENA IDENTIFICATION

Based upon the 1970 Origin & Destination Airline Passenger Traffic Survey[24] an examination was made of the rural air traveler data to determine (1) the percentage of onboard air travelers that are either local or connecting and, (2) the rural travel propensity as a function of population and frequency of service. A regression analysis of the low-density air traveler indicates that the low-density air demand consists of a mix of local and connecting travelers. The connecting traveler desires to connect with long-haul air trunk service which is available at all large and most medium-sized air hubs. At distances of about 100 miles from the hub, the connecting travelers comprise approximately 50% of the onboard passengers. As travel distances to the hub decrease, connecting passengers form the dominant demand; as distances increase, local travelers become dominant. The local air traveler tends to gravitate to routes radiating from the major trading center.

From this examination of air traveler data, the following conclusion is significant: to achieve an adequate load factor in a low-density region requires that both passenger sources (local and connecting) be combined; therefore, the potential low-density air transportation arena should comprise a major trading area where the major trading center is also an air hub offering good long-haul air trunk service. The boundaries of this low-density air arena would usually be the established boundaries of the major trading area; however, the boundaries could be established by the locus

of points equidistant between two air hubs offering equivalent service. There are 45 potential low-density air arenas in the United States that satisfy this criteria. In addition, there are 23 marginal arenas where the major trading center is concurrent with a small air hub or where a large or medium air hub is concurrent with the basic trading center rather than a major trading center. The arenas are shown in Figure 16 and listed in Table 4.

2. IDENTIFICATION OF PROMISING ARENA ROUTES

Table 5 tabulates the nonstop routes for the 34 city pairs analyzed. The first 20 city pairs are Type A nonstop routes with Phoenix, Arizona being the hub city which is both a major trading center and a major air hub. The 20 rural communities vary in population from below 2, 000 to about 25, 000 persons and travel distance between city pairs ranges from 60 to 250 miles. All but two of the city pairs can be provided with viable air service with a minimum of two nonstop round trip flights per day. The Type A city pairs, in general, represent the highest possible travel demand (all modes) and the greatest possible trip distance involved in local rural travel.

The next ten (21-30) city pairs are Type B nonstop routes with the hub cities being either a major trading center or a major air hub. Three hub cities were analyzed: Tucson, Arizona (major air hub); Las Vegas, Nevada (major air hub); and Charleston, West Virginia (major trading center). All of the ten city pairs proved nonviable for nonstop air service for each of the five aircraft analyzed. However, the two smaller aircraft did not lose money on three city pairs. In general, these Type B city pairs represent lower rural travel demands and shorter trip distances than the Type A city pairs.

The last four (31-34) city pairs are Type C. Here, the hub city is neither a major air hub nor a major trading center. The total travel

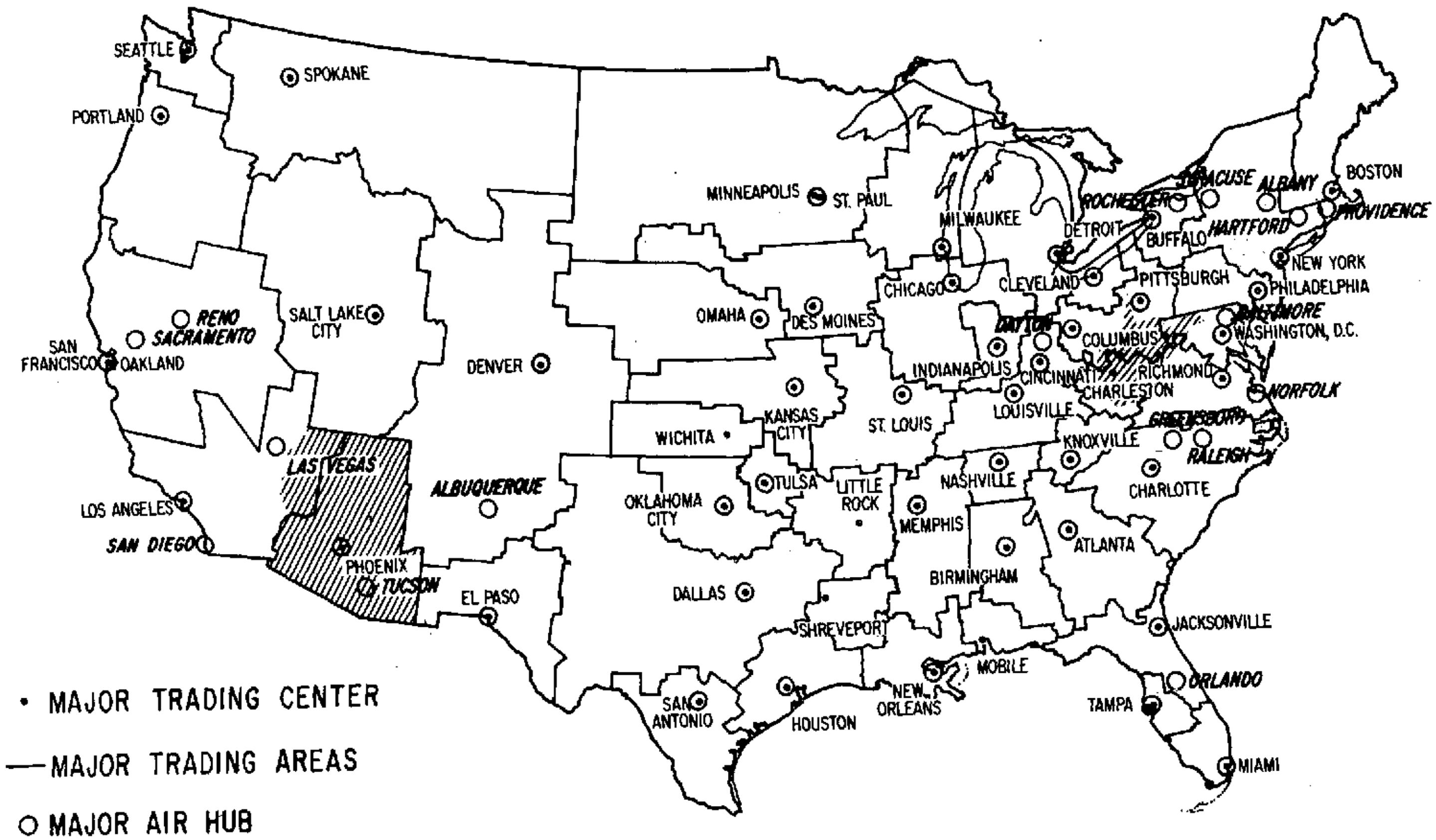

Figure 16. Low-Density Air Arenas

Table 4. Low-Density Air Arena/Hub Cities

MAJOR ARENAS

1. Atlanta, Ga.
2. Birmingham, Ala.
3. Boston, Mass.
4. Buffalo, N. Y.
5. Charlotte, N. Car.
6. Chicago, Illinois
7. Cincinnati, Ohio
8. Cleveland, Ohio
9. Columbus, Ohio
10. Dallas, Texas
11. Denver, Colo.
12. Detroit, Mich.
13. Des Moines, Iowa
14. El Paso, Texas
15. Houston, Texas
16. Indianapolis, Ind.
17. Jacksonville, Fla.
18. Kansas City, Kas.
19. Knoxville, Tenn.
20. Los Angeles, Calif.
21. Louisville, Ky.
22. Memphis, Tenn.
23. Miami, Florida
24. Milwaukee, Wisc.
25. Minneapolis/
26. St. Paul, Minn.
26. Nashville, Tenn.
27. New Orleans, La.
28. New York, N. Y.
29. Oklahoma City, Okla.
30. Omaha, Neb.
31. Philadelphia, Pa.
32. Phoenix, Arizona*
33. Pittsburgh, Pa.
34. Portland, Ore.
35. Richmond, Va.
36. Salt Lake City, Utah
37. San Antonio, Texas
38. San Francisco, Calif.
39. Seattle, Washington
40. Spokane, Wash.
41. St. Louis, Missouri
42. Tampa, Florida
43. Tulsa, Oklahoma
44. Washington, D. C.

MARGINAL ARENAS

1. Charleston, W. Va.*
2. Little Rock, Ark.
3. Mobile, Alabama
4. Shreveport, La.
5. Wichita, Kas.
6. Orlando, Fla.
7. Greensboro, N. C.
8. Raleigh, N. C.
9. Norfolk, Va.
10. Baltimore, Md.
11. Hartford, Conn.
12. Providence, R. I.
13. Albany, N. Y.
14. Syracuse, N. Y.
15. Albuquerque, N. M.
16. Tucson, Arizona*
17. Las Vegas, Nev.
18. San Diego, Cal.
19. Sacramento, Cal.
20. Reno, Nevada
21. Dayton, Ohio
22. Rochester, N. Y.

* In Selected Arenas

Table 5. City Pair Nonstop Route Viability

CITY PAIR, ARENA	TYPE OF NON-STOP ROUTE	VIABLE ROUTE	ACCEPTABLE AIRCRAFT: PIPER AZTEC	CESSNA 402B	BEECH 99A	SWEARINGEN	TWIN OTTER DHC-6
PHOENIX-AJO, ARIZ.	A	YES	X	X			
CLIFTON	A	YES	X	X			
DOUGLAS	A	YES	X				
FLAGSTAFF	A	YES	X	X	X		
FT. HUACHUCA	A	YES		X			
GLOBE	A	YES	X	X	X	X	
GRAND CANYON	A	YES	X	X	X	X	X
HOLBROOK	A	YES	X	X	X	X	
KINGMAN	A	YES	X	X			
LK. HAVASU CITY	A	YES	X	X	X	X	
NOGALES	A	YES	X	X	X		
PAGE	A	NO					
PARKER	A	NO					
PRESCOTT	A	YES	X	X	X	X	
SAFFORD	A	YES	X	X	X	X	
SAN MANUEL	A	YES	X	X	X		
SHOWLOW	A	YES	X	X	X	X	X
SPRINGERVILLE	A	YES	X	X	X	X	X
WILLCOX	A	NO					
WINSLOW	A	YES	X	X			
TUCSON-FT. HUACHUCA	B	NO					
DOUGLAS	B	NO					
LAS VEGAS-KINGMAN	B	NO					
PRESCOTT	B	NO					
CHARLESTON-BLUEFIELD, W. VA.	B	NO					
BECKLEY	B	NO					
CLARKSBURG	B	NO					
HUNTINGTON	B	NO					
MORGANTOWN	B	NO					
PARKERSBURG	B	NO					
PARKERSBURG-CLARKSBURG	C	NO					
HUNTINGTON	C	NO					
MORGANTOWN	C	NO					
BECKLEY-HUNTINGTON	C	NO					

demand is lower and trip distances shorter than the Type B city pairs. The four Type C city pairs all proved uneconomical for air service with a minimum of two nonstop round trips per day.

Figure 17 is a plot of total two-way daily travel demand (all modes) against air trip distance in miles for each of the 34 city pairs. The routes are noted as Type A, B, or C, and the viable and nonviable routes are noted as shaded and open circles, respectively. This plot shows a reasonable correlation of viability of air service as a function of both trip distance and total travel demand between communities. The figure shows that at a daily demand of 300 air service becomes viable at approximately 100 miles. Similarly, at a distance of 150 miles, the figure shows that a minimum total travel demand of approximately 200 daily person trips is required for viable air service with a minimum of two daily round trips. Nonstop air service will be economically marginal at demands and distances just below and to the left of the broken line (the viability boundary), and with still lower demand levels and shorter distances air service will become nonviable. In these marginal cases, the local modal split will determine the viability of nonstop air service. Routes other than nonstop should also be considered for these marginal* city pairs.

B. ARENA CHARACTERIZATION

This section presents the detailed data and methodology used in both the Arizona and West Virginia arenas. It includes the identification of routes studied, the characteristics of the cities involved in these routes, the demand for travel service between these cities, and the characteristics of both the automobile and air service used in the modal split simulations.

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* The example of scheduled "stop-on-demand" in Section IV-A-6 shows promise of converting some of these marginal nonstop routes to part of a viable low-density air system. Other routes such as linear multistop routes between two Type A hub cities should also be studied but are not covered in this report.

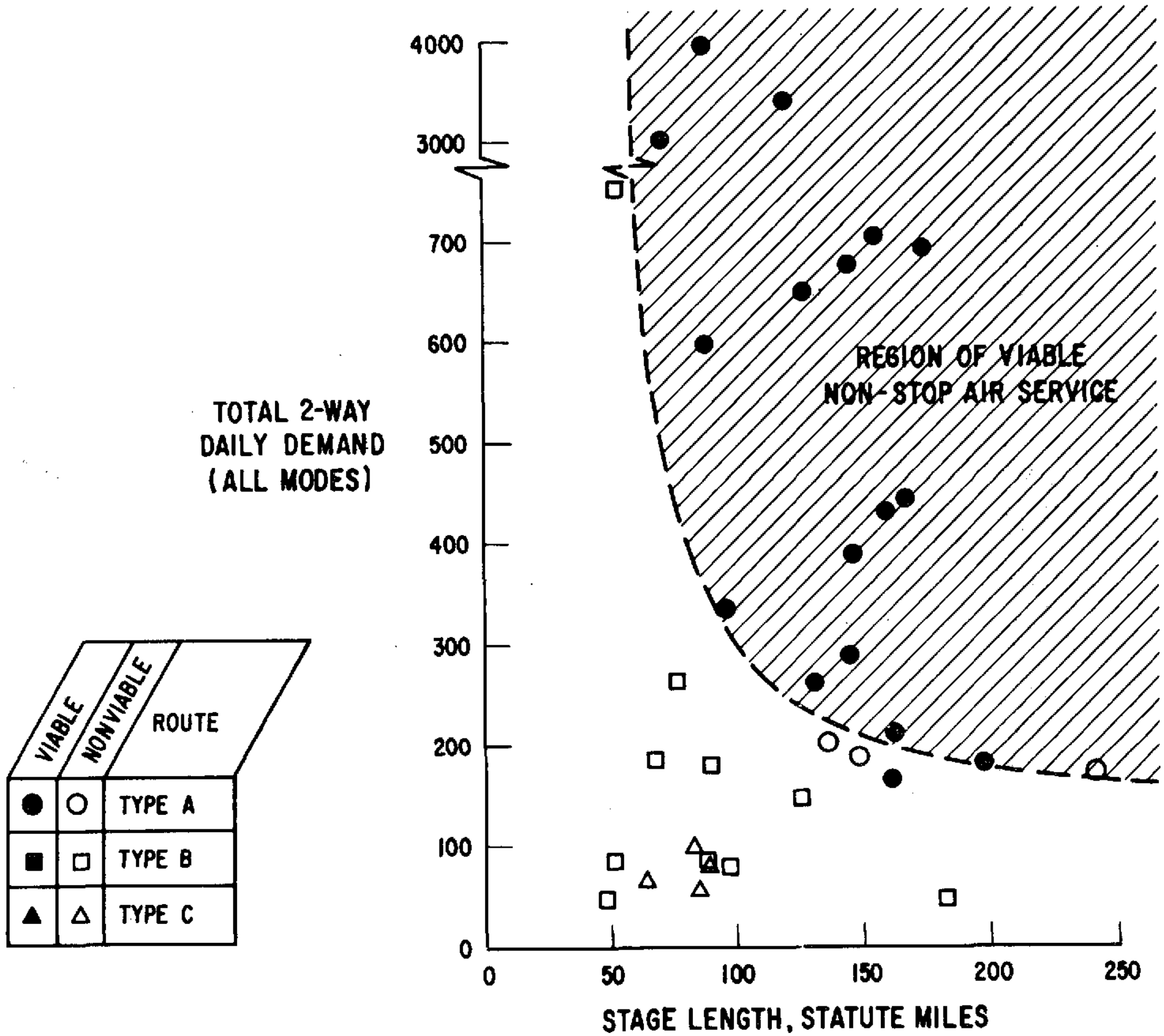

Figure 17. Viable Route Identification

1. ARIZONA

a. Route Identification

The routes studied in Arizona can be divided into two basic categories depending on whether or not they include the city of Phoenix. A matrix of potential routes between Phoenix and other Arizona cities, ordered by distance and population, is given in Table 6. It includes all of the Arizona cities having a population of over 2,500 persons and several smaller cities of particular interest.

Cities underlined in the table were subjected to a complete analysis. The others were eliminated because of one of three causes. Either they lacked sufficient overall travel demand to justify further consideration of air service, or initial modal split simulations indicated a serious lack of potential air demand because of their proximity to Phoenix, or they were already being adequately served by the current air system. As indicated, all routes of less than 50 air miles were eliminated as were most of those between 50 and 100 air miles.

In addition to the underlined cities, four other non-Phoenix city pairs survived the initial screening. These were Tucson-Fort Huachuca, Tucson-Nogales, Las Vegas-Kingman, and Las Vegas-Flagstaff.

b. City Descriptions

Population estimates for Arizona arena cities for 1975 were not directly available and therefore were formed as follows. First, 1970 Census of Population[25] data were obtained for each Arizona city and county. Since 1975 county population projections were available from state economic and planning agencies, it was possible for each Arizona county to form a growth factor which was the ratio of 1975 to 1970 population. It was

Table 6. Phoenix Population-Distance Matrix

CITIES POPULATION \ AIR DISTANCE ST. MILES	UNDER 50	50-100	100-150	150-200	200-250
OVER 50,000	SCOTTSDALE TEMPE MESA		TUCSON		
50,000 TO 25,000	GLENDALE		FLAGSTAFF	YUMA	
25,000 TO 10,000	CHANDLER SUN CITY CASE GRANDE	PRESCOTT		DOUGLAS	
10,000 TO 5,000	PARADISE VA. AVONDALE LUKE	GLOBE AJO ELOY	WINSLOW SAFFORD LAKE HAVASU	NOGALES KINGMAN* CLIFTON SIERRA VISTA FT. HAUCHUCA	
5,000 TO 2,500	PEORIA TOLLESON WILLIAMS EL MIRAGE EL MIRAGE CASHION BUCKEYE	SAN MANUEL SUPERIOR WICKENBURG SAN CARLOS MIAMI KEARNY COTTONWOOD	HOLBROOK WILLCOX	BENSON	
UNDER 2,500			PARKER	SPRINGERVILLE*	
UNDER 2,500 & RESORT			SHOW LOW	GRAND CANYON	PAGE

_______ TOWNS ANALYZED

* IN ADJACENT ARENAS

assumed that the ratio of city to county population would be the same in 1975 as it was in 1970 for each of the Arizona cities. Therefore, the 1970 population for each Arizona city was scaled up by the growth factor for its associated county to yield its 1975 population. Las Vegas was handled in a slightly different manner. Its 1975 population was obtained by a linear extrapolation of its 1960 and 1970 populations. Table 7 contains the pertinent data for all of the procedures described above as well as the 1975 city population estimates.

For the purpose of this analysis these smaller cities in proximity to larger ones were grouped and their total population assigned to the larger city. Thus, Phoenix includes its suburbs, Globe includes Miami and Claypool, Safford includes Pima and Thatcher, Springerville includes Eager, Clifton includes Morenci, San Manuel includes Mammoth, Fort Huachuca includes Sierra Vista, Show Low includes Pinetop and Snowflake, and Tucson includes South Tucson.

For the purpose of the modal split simulations, the populations of Phoenix and Tucson were further divided in order to more accurately model the heterogeneity of population density throughout the metropolitan areas. Phoenix was subdivided into 19 areas consistent with those shown in "Inside Phoenix, 1969" and Tucson was divided into a northern and a southern section to better model its population distribution.

Family income estimates for Arizona arena cities for 1975 were formed as follows. From the Arizona Department of Economics and Planning, per capita income projections for Arizona counties for 1975 were obtained in 1975 dollars. These were converted to 1971 dollars by multiplying them by 0.9233 which was derived from the inflator series, Table B-2 in "Arizona State and County Personal Income Projections,

Table 7. Arizona Population and Income Projections for 1975

City	County	1970 City Population	1970 County Population	1975 County Population	County Growth Factor	1975 City Population	1975 Median Income
Ajo	Pima	5,900	351,700	416,300	1.184	7,000	10,459
Clifton	Greenlee	6,200	10,300	10,600	1.029	6,400	11,634
Douglas	Cochise	12,500	61,900	65,200	1.053	13,200	10,137
Flagstaff	Coconino	26,100	48,300	51,000	1.056	27,600	8,535
Ft. Huachuca	Cochise	13,300	61,900	65,200	1.053	14,000	10,137
Globe	Gila	13,000	29,300	31,900	1.089	14,200	8,320
Grand Canyon	Coconino	1,000	48,300	51,000	1.056	1,100	8,535
Holbrook	Navajo	4,800	47,600	52,000	1.092	5,200	6,402
Kingman	Mohave	7,300	25,900	34,600	1.336	9,800	8,326
Lake Havasu	Mohave	5,200	25,900	34,600	1.336	6,900	8,326
Las Vegas		191,300				233,500	12,238
Nogales	Santa Cruz	8,900	14,000	16,200	1.157	10,300	8,535
Page	Coconino	1,400	48,300	51,000	1.056	1,500	8,535
Parker	Yuma	1,900	60,800	69,900	1.150	2,200	11,315
Phoenix	Maricopa	825,800	968,500	1,167,100	1.205	995,100	11,204
Prescott	Yavapai	13,100	36,800	40,600	1.103	14,400	8,326
Safford	Graham	8,800	16,600	17,700	1.066	9,400	7,682
San Manuel	Pinal	6,300	68,600	72,000	1.050	6,600	9,175
Show Low	Navajo	5,000	47,600	52,000	1.092	5,500	6,402
Springerville	Apache	2,300	32,300	36,400	1.127	2,600	6,252
Tucson	Pima	269,200	351,700	416,300	1.184	318,700	10,459
Willcox	Cochise	2,600	61,900	65,200	1.053	2,700	10,137
Winslow	Navajo	8,100	47,600	52,000	1.092	8,800	6,402

1975-1980."[26] In "Inside Phoenix, 1971"[27] the median family income for the greater Phoenix area (97% of the Maricopa County population) is given. For that year the ratio of family income to per capita income is 2.326 for Maricopa County. Therefore, the 1975 family income for all other counties was obtained by multiplying the 1975 per capita income (in 1971 dollars) by 2.326. All cities were assigned a family income on the basis of their county. The same multiplier was used to convert Las Vegas data from per capita to family income. The last column of Table 7 contains the 1975 family income in 1971 dollars for each of the Arizona arena cities.

The city of Phoenix again is handled somewhat differently. A separate income projection was made for each of its 19 areas. The basic income data used was taken from "Inside Phoenix, 1971."[28] While this income data is for families, it is for the year 1971. Projections to 1975 were obtained by multiplying each area's income median by 1.1929 which is the ratio of 1975 to 1971 Maricopa County income. These projections are contained in the last column of Table 7.

In order to get traveler family income as opposed to population family income, all of the values in the table were multiplied by an additional factor of 1.2 prior to modal split simulation runs. Selection of this value is based on a review of all of the traveler income data developed for previous studies. The Arizona arena is most like the short California city pairs (business fraction = 0.1675, trip lengths of 50-200 miles), where over a very wide range of population median income ($1,000-$13,000) the ratio of traveler to population income is between 1.15 and 1.25. Because of this uniformity over a wide range of income and the fact that income data is available only on a county basis, use of a constant factor between population and traveler income is felt to be adequate.

c. Local Intracity Travel Functions

The local travel functions are tabular functions of cost and time versus distance which are used to compute the cost and time from the traveler's exact door location to each candidate port at both the origin and destination ends of the trip. Two tables are provided for each city, one corresponding to driving a car and the other corresponding to a combination of public modes and "kiss and ride" wherein a person is driven to or from a port by another person. Cost parameters and the general ground rules for the use of these tables, along with a combined table for the Phoenix area is given in Table 8.

Table 8. Local Travel Functions

Car

- 4¢/mile
- Required for car travelers on both ends of trip
- Optional (drive and park) for non-car travelers in resident city
- Mileage based on travel along orthogonal city streets, rather than straight line distances

Other (Kiss and Ride, Taxi, Bus/Limousine)

- 8¢/mile plus $4/hour (one-way)
- Required at visited city, optional in resident city for non-car travelers

Phoenix Local Travel Functions

Distance (mi)	Time (min)	Speed (mph)	Car Cost ($)	Other Cost ($)
0	0	-	0	0
2	5	24	0.08	0.49
8	15	36	0.32	1.64
22	35	42	0.88	4.09
72	95	50	2.88	12.09

Similar tables were used for Tucson and the smaller cities. These tables are linearly interpolated (and extrapolated if necessary) by the computer program to yield continuous cost and time relationship with distance. Travel times for these tables were formulated using basic data obtained from local agencies and automobile club studies. Travel times from city center to the local airport for each city are given as part of Table 9.

d. Arizona Intercity Travel Demand

The basis for the demand calculations was an origin and destination data input obtained from the Arizona Department of Highways.[29] A reasonably good fit to the gravity model was achieved using the six selected city pairs in Table 10. The coefficient B of the population product was then applied to the 1975 population projections and the 1960 origin and destination (O & D) data[30] to predict 1975 intrastate vehicle trips between all city pairs. A car occupancy factor of 2.39 and a resident car ownership factor of 90 percent was then applied to convert the data to intrastate person trips by Arizonians. (It was assumed that nonresident travelers bringing their cars into the state would continue to use them for intrastate trips.) Because of the extremely small percentage of travel by air and bus in 1960, the car data was taken to be representative of the total travel generated between city pairs. The resulting two-way demand for 1975 is shown in Table 11.

From the results of the modal split simulations, local air demand for 1975 was calculated as shown in the fourth column of Table 12. To obtain the percent of connecting air passengers, the function of Figure 18 was evaluated for each of the intercity distances, and applied to the local air data to obtain connecting air demand. These figures were then summed to obtain the total daily air demand shown in Table 12. Note that the total air demand for these nominal modal split runs appears to be sufficient to support air service for at least some of the city pairs. The economics of such operations will be discussed in Section III-D.

Table 9. Arizona Arena Airports

	Distance from CBD (mi)	Time from CBD (min)	Processing Time (min)	Parking Time (min)	Parking Cost ($/day)
Ajo	6	7	6	1.5	
Clifton	10	12	6	1.5	
Douglas	12	14	6	1.5	
Flagstaff	5	6	6	1.5	
Ft. Huachuca	7	10	6	1.5	
Globe	3	9	6	1.5	
Grand Canyon	9	14	6	1.5	
Holbrook	4	5	6	1.5	
Kingman	9	13	6	1.5	
Lake Havasu City	5	8	6	1.5	
Las Vegas	8	11	10	6	1.25
Nogales	8	11	6	1.5	
Page	2	3	6	1.5	
Parker	2	4	6	1.5	
Phoenix	5	10	17	6	1.75
Prescott	10	13	6	1.5	
Safford	6	7	6	1.5	
San Manuel	3	5	6	1.5	
Show Low	3	4	6	1.5	
Springerville	3	5	6	1.5	
Tucson	7	15	12	6	1.50
Willcox	4	6	6	1.5	
Winslow	2	5	6	1.5	

Table 10. Arizona Gravity Model Calibration

City Pair	Population Product (x 10^9)	Distance (mi)	Actual Daily Trips (1960)	Estimated Trips
Phoenix - Ajo	2.98	106	322	480
- Globe	6.28	73	1673	1294
- Holbrook	1.80	202	135	154
- Nogales	2.27	173	234	219
- Safford	3.68	162	344	338
- Springerville	.83	222	94	78

$$T = A \times \frac{(PP)^B}{(D)^C}$$

(As defined in Section II-E-1)

A = 55394
B = 0.735
C = 1.19

Table 11. Arizona City Pair Total Demand Projections

CITY PAIR		POP. PRODUCT (x 10^9)		TWO-WAY DEMAND (Person-Trips)	
		1960	1975	1960	1975
Phoenix -	Ajo	2.98	6.97	322	602
	Clifton	3.24	6.39	103	170
	Douglas	6.22	13.14	114	186
	Flagstaff	9.52	27.46	1589	3448
	Ft. Huachuca	2.33	13.93	116	435
	Globe	6.28	14.13	1673	3045
	Grand Canyon		1.09	354	697
	Holbrook	1.80	5.17	135	293
	Kingman	2.37	9.75	159	448
	Lake Havasu City		6.87		392
	Nogales	2.27	10.25	234	709
	Page		1.49	90	177
	Parker	0.86	2.19	101	207
	Prescott	6.73	14.3	2309	3995
	Safford	3.68	9.35	344	681
	San Manuel	3.09	6.57	193	338
	Showlow	1.78	5.47	315	652
	Springerville	0.83	2.59	94	217
	Willcox	1.28	2.69	112	193
	Winslow	4.66	8.76	168	265
Tucson -	Douglas	2.89	4.21	477	630
	Ft. Huachuca	1.08	4.46	1218	3471
Las Vegas -	Kingman	.865	2.29		216
	Prescott	2.46	3.36		42

Table 12. Arizona 1975 Air Demand

City Pairs	Local Demand			Daily 2-Way Connecting Air Demand	Total 2-Way Daily Air Demand
	Total 2-Way Daily Demand (All Modes)	Nominal Air Modal Split	Nominal 2-Way Local Air Demand		
Phoenix - Ajo	602	.0188	11.3	20.0	31.3
- Clifton	170	.0844	14.4.	10.4	24.3
- Douglas	186	.0506	9.4	5.5	14.9
- Flagstaff	3448	.0158	54.5	101.5	156.0
- Ft. Huachuca	435	.0358	15.6	12.2	27.8
- Globe	3045	.0176	53.6	131.4	185.0
- Grand Canyon	697	.0438	30.5	40.5	71.0
- Holbrook	293	.0670	19.6	17.4	37.0
- Kingman	448	.0338	15.1	6.4	21.5
- Lake Havasu City	392	.0536	21.0	17.9	38.9
- Nogales	709	.0276	19.6	15.9	35.5
- Page	177	.0536	9.5	3.7	13.2
- Parker	207	.0384	7.9	7.6	15.5
- Prescott	3995	.0060	24.0	28.2	52.2
- Safford	681	.0378	25.7	22.8	48.5
- San Manuel	338	.0358	12.1	19.0	31.1
- Showlow	652	.0802	52.3	52.3	104.6
- Springville	217	.0940	20.4	15.4	35.8
- Wilcox	193	.0482	9.3	5.7	15.0
- Winslow	265	.0466	12.3	12.8	25.1
Tucson - Douglas	630	.0136	8.6	2.1	10.7
- Ft. Huachuca	3471	.0032	11.1	2.8	13.9
Las Vegas - Kingman	216	.0086	1.9	3.4	5.3
- Prescott	42	.0662	2.7	1.6	4.3

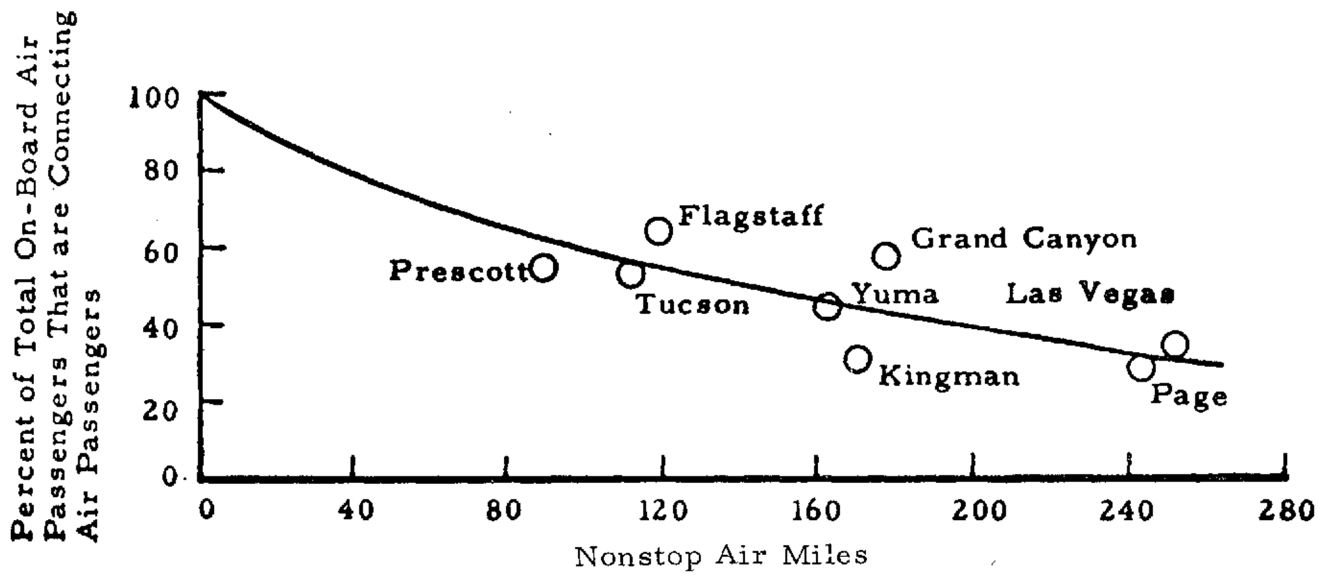

Figure 18. Phoenix, Arizona Connecting Air Passengers

The 1967 Census of Transportation[31] tape was utilized to obtain the business travel fraction and the traveler trip duration and party size distributions for both business and nonbusiness travelers for the Arizona arena. In order to get an adequate sample size, households in the entire Western Region (13 western continental states) were used. However, only trips between 100 and 300 miles that either originated in a rural region or terminated in a rural region were counted. The 100- to 300-mile interval was selected to be consistent with the general range of distances between the city pairs studied in the Arizona arena. The tape contained a total of 3406 trips which met the above constraints. Of these 3406 trips, 544 were business and 2862 were nonbusiness trips. There were 1787 trips originating from an urban region to a destination in a rural region and 1619 trips

originating in a rural area with a destination either in an urban area or a rural area. The resulting Arizona arena traveler characteristics are given in Table 13.

Table 13. Arizona Traveler Characteristics

Business Fraction .1605	Business	Nonbusiness
Party Size		
1	0.588	0.140
2	0.226	0.298
3	0.065	0.144
4	0.065	0.216
5	0.009	0.121
6	0.047	0.081
Trip Duration (Days)		
Lognormal Median	0.8	1.4
Lognormal Variance	2.9	2.9

e. Intercity Travel Mode Characteristics

Characteristics of the Arizona arena airports from the traveler's point of view were given in Table 9. Distances and auto travel times from the city center to the airport are shown as well as the processing and parking times consistent with the definitions established for the modal split model in Section II. F. 2. 3. Parking costs are the current daily rates in effect at these airports; it is assumed that they will be the same in 1975.

The baseline air traveler waiting time distribution used for all service paths had a mean waiting time of two hours. This corresponds roughly to a schedule with an early morning departure (i. e., between 7:00 and 9:00 AM) and a late afternoon departure (i. e., between 4:00 and 6:00 PM).

Intercity car distances, costs, and travel times for Arizona city pairs for 1975 are given in Table 14. Values are from the city centers, which in the cases of Phoenix and Tucson are not necessarily the automobile ports used by many of the simulated travelers since these cities were not modeled as point sources. Furthermore, for some city pairs, several routes are available and therefore multiple paths were modeled. In these cases the most popular route from the CBD is used in the table.

The basic data source for this effort was the 1971-72 AAA Arizona-New Mexico map augmented by the AAA Colorado River map, Indian Country map, and city maps for Phoenix, Tucson, and Las Vegas. Interstate highway construction was projected to 1975. Travel times were AAA values modified as appropriate to reflect recent construction, and the fact that these roads will be traveled by Arizona residents. Perceived car costs were modeled at 4 cents per mile.

2. WEST VIRGINIA

a. Route Identification

The routes studied in West Virginia can be divided into two basic categories depending on whether or not they include the city of Charleston. A matrix of potential routes between Charleston and other West Virginia cities, ordered by distance and population, is given in Table 15. It includes all of the West Virginia cities having a population of over 2,500 persons.

Cities underlined in the table survived an initial screening and were subjected to a complete analysis. The others were eliminated because of one of three causes. Either they lacked sufficient overall travel demand to justify further consideration of air service, or previous modal split simulation experience indicated a serious lack of potential air demand because of

Table 14. Baseline Arizona Intercity Travel Mode Characteristics

City Pair		Air			Car		
		Miles	Time (hr)	Cost	Miles	Time (hr)	Cost
Phoenix -	Ajo	88	0.56	13.40	106	2.09	4.24
	Clifton	162	1.02	20.20	205	4.66	8.20
	Douglas	199	1.25	23.60	240	4.53	9.60
	Flagstaff	119	0.75	16.20	144	2.5	5.76
	Ft. Huachuca	160	1.01	20.00	194	3.6	7.76
	Globe	71	0.46	11.80	87	2.28	3.48
	Grand Canyon	174	1.09	21.30	223	4.17	8.92
	Holbrook	145	0.91	18.60	235	4.13	9.40
	Kingman	167	1.05	20.70	185	3.65	7.40
	Lake Havasu City	147	0.93	18.80	207	3.75	8.28
	Nogales	155	0.98	19.60	187	3.4	7.48
	Page	242	1.51	27.60	274	5.2	10.96
	Parker	137	0.87	17.90	172	3.0	6.88
	Prescott	87	0.56	13.30	99	1.85	3.96
	Safford	145	0.91	18.60	163	3.78	6.52
	San Manuel	97	0.62	14.20	133	2.7	5.32
	Show Low	127	0.80	17.00	176	4.38	7.04
	Springerville	163	1.03	20.30	222	5.33	8.88
	Willcox	149	0.94	19.00	203	3.6	8.12
	Winslow	132	0.84	17.50	204	3.54	8.16
Tucson -	Douglas	90	0.34	10.00	120	2.33	4.80
	Ft. Huachuca	51	0.58	13.60	74	1.4	2.96
Las Vegas -	Kingman	89	0.57	13.50	104	2.1	4.16
	Prescott	183	1.15	22.10	248	4.78	9.92

Table 15. Charleston Population-Distance Matrix

AIR DISTANCE ST. MILES / CITIES POPULATION	UNDER 50	50-100	100-150	150-200	200-250
OVER 50,000	HUNTINGTON				
50,000-25,000		PARKERSBURG	WHEELING* FAIRMONT* MORGANTOWN*	WEIRTON*	
25,000-10,000	ST. ALBANS S. CHARLESTON	VIENNA* BECKLEY BLUEFIELD	CLARKSBURG* MOUNDSVILLE*		MARTINSBURG*
10,000-5,000	PT. PLEASANT* NITRO DUNBAR	WESTON* BUCKHANNON* PRINCETON WILLIAMSON	NEW MARTINSVILLE* WESTOVER* GRAFTON* ELKINS*	KEYSER*	
5,000-2,500	RAVENSWOOD RIPLEY MONTGOMERY HURRICANE OAK HILL KENOVA MOUNT GAY LOGAN	WILLIAMS-TOWN* PADEN CITY* SALEM* WELCH RICHWOOD MULLENS HINTON	BENWOOD* WELLSBURG* PHILLIPPI* McMECHEN* BRIDGEPORT* MANNINGTON* SHINNSTON* KINGWOOD*	FOLLANSBEE* CHESTER*	CHARLESTOWN*

* IN ADJACENT ARENAS

______ TOWNS ANALYZED

their proximity to Charleston, or they were already being served by the current air system. As indicated, almost all routes of less than 50 air miles were eliminated as were most of those for greater distances.

In addition to the underlined cities, four other non-Charleston pairs survived the initial screening. These were Huntington-Beckley, Huntington-Parkersburg, Parkersburg-Clarksburg, and Parkersburg-Morgantown.

b. City Descriptions

Population estimates for West Virginia arena cities for 1975 were formed as follows. City populations from the 1960 and the 1970 census were linearly extrapolated to 1975. As a further check the 1960 and 1970 county census data was used to evaluate population trends on a county basis and was found to be in good agreement with the city data. Table 16 contains the basic 1960 and 1970 city population data as well as the projections to 1975.

Table 16. West Virginia Population Data

City	County	Population 1960	Population 1970	Population 1975
Beckley	Raleigh	18,642	19,884	20,505
Bluefield	Mercer	19,256	15,921	14,254
Charleston	Kanawha	62,240	47,203	39,685
Clarksburg	Harrison	10,604	9,353	8,728
Huntington	Cabell	25,820	22,648	21,062
Morgantown	Monogalia	22,487	29,431	32,903
Parkersburg	Wood	33,581	32,605	32,117

The construction of 1975 family median income data was somewhat more complex. First, the 1965 county family income was obtained by persons per family ratio for each county. To make a city to county correction for income a city to county income ratio was formed for each city. This data was directly available for Charleston, Clarksburg, and Parkersburg. For the remaining cities an average of the values for the above three cities was used. This city to county income ratio was then multiplied by the 1975 county family income to get the 1965 family income for each city. To get 1975 values, conversion factors from the National Planning Association for West Virginia[32] were used. This 1965 conversion factor was 1. 49, except for Charleston (1. 47) and Huntington (1. 54). Multiplication of the 1965 city family income data by this conversion factor yielded 1975 city family income (in 1965 dollars). A final multiplication by 1. 23 converted the 1975 income to 1970 dollars. These final city family incomes for 1975 as well as the basic data for the pertinent conversion steps are given in Table 17.

Again as in the Arizona arena in order to get traveler family income as opposed to population traveler income all of the values in the table were multiplied by an additional factor of 1. 2 prior to modal split simulation runs. The justification for this factor is given in Section III. B. 1. b.

c. Local Intracity Travel Functions

The local intracity travel functions for West Virginia were developed using the same ground rules as for Arizona. These ground rules were given in Table 8 and are discussed in Section III. B. 1. c. However, the West Virginia local travel speeds are generally somewhat slower than those in Arizona. This is primarily due to bottlenecks caused by the nature of the terrain. Travel times from the city center to the local airport for each city is given as part of Table 18.

Table 17. West Virginia Income Data

City	County	1965 County Income	City/ County Ratio	1965 City Income	1975 Income (in 1965 $)	1975 Income (in 1970 $)
Beckley	Raleigh	4,916	1.076	5,290	7,882	9,695
Bluefield	Mercer	5,272	1.076	5,673	8,453	10,397
Charleston	Kanawha	6,897	1.048	7,228	10,625	13,069
Clarksburg	Harrison	6,116	1.107	6,770	10,087	12,407
Huntington	Cabell	6,285	1.076	6,763	10,415	12,810
Morgantown	Mongolia	5,550	1.076	5,972	8,898	10,945
Parkersburg	Wood	7,002	1.033	7,233	10,777	13,256

Table 18. West Virginia Arena Airports

City	Distance from CBD (mi)	Time from CBD (min)	Processing Time (min)	Parking Time (min)	Parking Cost ($/day)
Beckley	4	9	6	3	
Bluefield	3	7	6	3	
Charleston	5	11	10	6	1.25
Clarksburg	9	18	6	3	
Huntington	5	13	8	6	
Morgantown	3	7	6	3	
Parkersburg	8	18	6	3	

d. <u>West Virginia Intercity Travel Demand</u>

The basis for the total demand was 1965 origin and destination data collected from various sources as part of a study of potential STOL service. [33] For certain city pairs the bus and air modes generated a substantial percentage of total traffic so total demand figures were based on the sum of air, bus, and automobile demand for each city pair. The projections for 1975 utilized a gravity model based on a best fit of the six city pairs shown in Table 19. However, one additional factor had to be taken into account. Planned improvements in interstate highways would have resulted in considerably shorter automobile distances for two of the city pairs. Therefore, use was made of the distance factor coefficient of the gravity model to increase the total demand to reflect the reduced ground distances. Table 20 summarizes the final results for the ten West Virginia city pairs.

Modal split simulations were run to permit computation of local air demand. The curve of Figure 19 was used to derive percentages of connecting air passengers, and the final results for air demand are shown in Table 20. Note that the total demand in this arena is an order of magnitude less than for the Arizona area. This should not be surprising since the intercity distances are much shorter and by 1975 excellent interstate highways will connect all of the major cities in the region. These factors tend to increase the use of the automobile and consequentially decrease the use of air travel. Furthermore, city populations in the West Virginia arena have been decreasing and current CAB statistics indicate a substantial drop in air traffic compared to previous years.

Table 19. West Virginia Gravity Model Calibration

City Pair	Population Product ($\times 10^9$)	Distance (mi)	Actual Daily Trips (1960)	Estimated Trips
Charleston - Beckley	1.05	58	310	393
- Clarksburg	0.55	147	58	59
- Huntington	1.33	48	984	611
- Morgantown	1.42	187	90	70
- Parkersburg	1.81	77	231	339
Parkersburg - Clarksburg	0.33	82	111	114

$$T = A \times \frac{(PP)^B}{(D)^C}$$

(As defined in Section II. E. 1)

A = 281644

B = 0.578

C = 1.63

Table 20. West Virginia City Pair Total Daily Demand Projections

City Pair		Population Product (x 10^9) 1965	Population Product (x 10^9) 1975	2-Way Daily Demand 1965	2-Way Daily Demand 1975	Distance Factor	1975 2-Way Daily Demand With Distance Factor
Charleston	- Beckley	1.054	.814	310	266	1.000	266
	- Bluefield	.963	.566	70	51	1.000	51
	- Clarksburg	.546	.346	58	45	1.872	84
	- Huntington	1.326	.836	984	754	1.000	754
	- Morgantown	1.421	1.306	90	86	1.720	148
	- Parkersburg	1.811	1.275	231	188	1.000	188
Huntington	- Beckley	.467	.432	71	68	1.000	68
	- Parkersburg	.802	.676	95	86	1.000	86
Parkersburg	- Clarksburg	.330	.280	111	101	1.000	101
	- Morgantown	.860	1.057	53	60	1.000	60

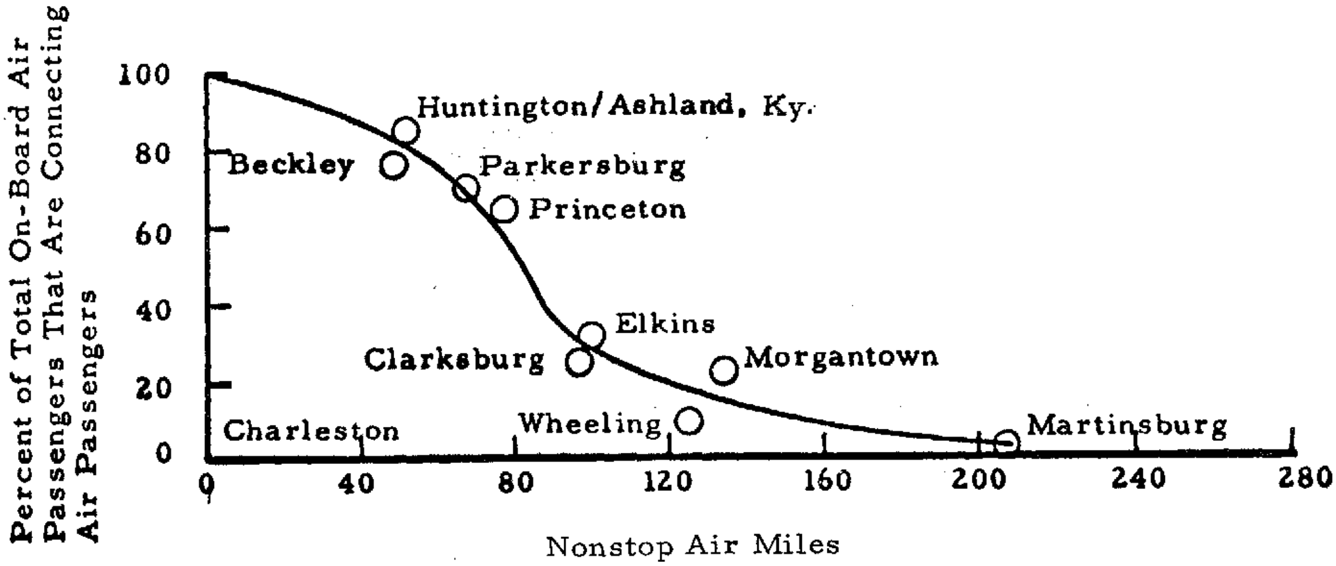

Figure 19. Charleston, West Virginia - Percent Connecting Air Passengers

The 1967 Census of Transportation[34] tape was utilized to obtain the business travel fraction and the traveler trip duration and party size distributions for both business and nonbusiness travelers for the West Virginia arena. In order to get an adequate sample size, households in the entire 11 state Appalachian Region were used. This region consists of all or parts of Alabama, Georgia, Kentucky, Maryland, North Carolina, Ohio, Pennsylvania, South Carolina, Tennessee, Virginia and West Virginia. However, to be consistent with the city pairs studied in the West Virginia arena, only trips between 50 to 250 miles, which either originated in a Non-Standard Metropolitan Statistical Area (NSMSA) or terminated in a NSMSA were counted. The tape contained a total of 5781 trips which met the above constraints. Of these trips 767 were business and 5014 were nonbusiness trips. There were 3258 trips originating in an SMSA and 2523

trips originating in a NSMSA. The resulting West Virginia Arena traveler characteristics are given in Table 21.

Table 21. West Virginia Traveler Characteristics

	Business	Nonbusiness
Business Fraction: .1578		
Party Size		
1	0.615	0.163
2	0.248	0.256
3	0.058	0.188
4	0.064	0.161
5	0.007	0.144
6+	0.008	0.088
Trip Duration (Days)		
Lognormal Median	0.98	1.2
Lognormal Variance	3.25	2.9

e. Intercity Travel Mode Characteristics

Characteristics of the West Virginia Arena airports from the traveler's point of view were given in Table 8. Parking costs are the current daily rates in effect at these airports; it is assumed that they will be the same in 1975.

The baseline air traveler waiting time distribution used for all service paths had a mean waiting time of two hours. This corresponds roughly to a schedule with an early morning departure (i. e., between 7:00 and 9:00 AM) and a late afternoon departure (i. e., between 4:00 and 6:00 PM).

Intercity car distances, costs, and travel times for West Virginia city pairs for 1975 are given in Table 22. Values are from the city

centers. Perceived car costs were modeled at 4 cents per mile. Tolls on the West Virginia turnpike are included when appropriate for trips between Charleston and Beckley or Bluefield. Car times are based on average speeds of 50 mph for trunklines and 60 mph for interstate highways. For congested travel within city boundaries, it was assumed that the speeds would be half the average speeds used above.

Table 22. Baseline West Virginia Intercity Travel Mode Characteristics

City Pair		Air			Car		
		Miles	Time (hr)	Cost	Miles	Time (hr)	Cost
Charleston	- Beckley	48	.32	16.50	58	1.09	3.70
	- Bluefield	77	.50	19.00	106	1.89	6.44
	- Clarksburg	97	.62	20.50	113	1.95	4.52
	- Huntington	52	.34	16.75	48	.93	1.92
	- Morgantown	126	.80	23.00	153	2.63	6.12
	- Parkersburg	68	.44	18.00	77	1.36	3.08
Huntington	- Beckley	86	.55	19.50	108	1.87	4.32
	- Parkersburg	90	.58	20.00	105	1.83	4.20
Parkersburg	- Clarksburg	65	.42	17.75	82	1.44	3.28
	- Morgantown	84	.54	19.25	122	2.16	4.88

C. AIRCRAFT AND EQUIPMENT CHARACTERISTICS

1. REGULATIONS

a. Economic Regulations

The Civil Aeronautics Act of 1938[35] established a class of unregulated small aircraft operators which are subject to minimum

economic regulations. Under Part 298[36] these carriers are exempt from certificate obligations and other regulatory requirements such as filing rates, fares, changes, services and detailed statistical and financial reports. Essentially these carriers must simply register with the CAB, maintain liability insurance, and file schedules and periodic traffic reports.

The intent of the CAB has been, and still is, not to protect these carriers against either air or surface transportation. The CAB relies on the forces of competition, in place of regulation, to foster such service and thus allows air taxi operators unlimited freedom of entry and exit into markets.[37] Since July 1, 1969 the CAB has designated a new subclass of commuter air carriers which (1) must perform at least five round trips per week to two or more points and publish flight schedules which specify the times, days of the week, and places between which flights are performed, or (2) transports mail by air pursuant to a current contract with the Post Office Department.

There are several types of scheduled air taxi or commuter air carriers whose service characteristics can be grouped into the following categories:

1) Those operating pursuant to contracts with domestic trunk or local service carriers over prior routes of these carriers.
2) Those providing commuter service in high-density short-haul markets with or without competition from other carriers.
3) Those providing primarily low-density service between urban and rural areas.
4) Those providing only scheduled mail service.

To operate under Part 298[38] an air taxi or commuter air carrier must use equipment which does not have a maximum certificated takeoff weight of more than 12,500 pounds. This limitation was established to insure that air taxi aircraft would not be competitive with the aircraft of certificated

carriers. However, on September 27, 1971, the CAB in an initial decision[39] now limits such aircraft to a maximum capacity of 30 passengers or a maximum weight capacity (payload) of 7,500 pounds, except in Alaska or Hawaii where the 12,500-pound weight limitation remains.

b. Operational Regulations

Air taxi or commuter air carriers may perform operations under Part 135 of the Federal Aviation Act.[40] Aircraft may also be certified under Part 23.[41] The larger certificated carriers must operate under more rigid FAA operational and certification requirements under Part 121[42] and 25[43] respectively.

However, to operate under Part 135[44] and 23[45] an aircraft cannot have a maximum certificated takeoff gross weight of more than 12,500 pounds. In addition, an aircraft with a passenger capacity of more than nine cannot be certificated under Part 23.[46]

A summary of scheduled air carrier regulations as a function of aircraft passenger capacity is shown in Section II, Figure 11. Operations under Part 121[47] can be seen to increase maintenance requirements, managerial personnel qualifications, training, aircraft dispatch, and control and safety requirements. For example, under Part 121[48] operators must maintain complete maintenance manuals for each major component covering time limitations for overhauls, inspections, and checks of airframe, engines, propellers, and appliances. Key managerial personnel must have specific experience and hold appropriate certificates. A formal FAA approved training program must be established. Positive in-flight control of all aircraft must be maintained and redundancy in safety equipment must be provided.

Testimony by air taxi operators on the recent weight limitation indicated that most could not conduct operations under Part 121[49] profitably.

The FAA has also indicated that it has no plans for permitting operation of aircraft weighing more than 12,500 pounds except under the provisions of Part 121.[50] Therefore, it appears that only those operators serving high-density short-haul markets or markets with unusual peak hour demands will be able to effectively use 30-passenger aircraft.

c. <u>Financing Regulations</u>

Under Public Law 85-307, as amended by Public Law 87-820, 89-670, and 90-568,[51] there is an aircraft loan guarantee program administered by the Department of Transportation. The benefits of this program are, however, limited to air carriers holding a certificate of public convenience and necessity issued by the CAB. Air Taxi or commuter air carriers are accordingly ineligible for such loan guarantees.

It should be noted that one of the major factors enabling transportation or public utility companies to obtain necessary financing is the certificate of convenience and necessity or franchise. Such a certificate or franchise in many cases serves as collateral to financial institutions in securing the loans. It is no doubt that because of these factors the National Air Transportation Conference (NATC) which is composed of many of the leading commuter air carriers, is seeking route protection and limited certification and federally guaranteed loans for the refinancing of old as well as new equipment.[52]

2. PERFORMANCE

Aircraft performance plays a key role in establishing the viability of air service. Cruise speed, climb speed, and rate of climb are factors in the determination of elapsed trip time which is one of the quantities the traveler considers when making travel mode choices. Aircraft fuel consumption, which generally accounts for between 20 to 30% of direct operating costs at rates charged to small air service operators, is

for that reason also an important aircraft performance characteristic upon which air service viability depends. These performance characteristics are discussed in detail below.

a. Block Time

Block time is defined here as the total engine on time during a trip. This includes taxi time, takeoff and landing time, climb and descent time, maneuver time, and cruise time. The model adopted in this study for the aircraft climb and cruise profile, which in turn was used to determine climb and cruise times, is shown in Figure 20.

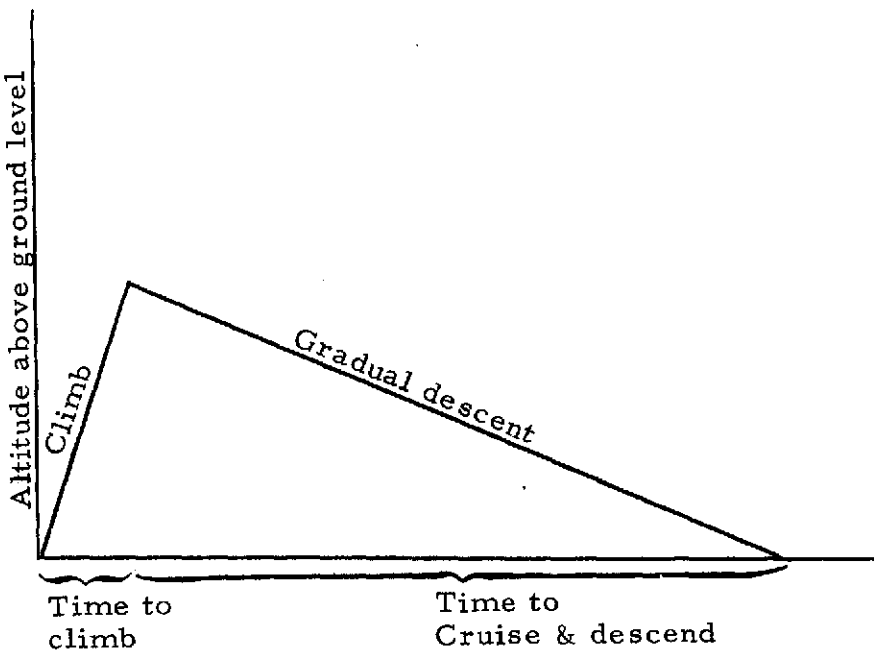

Figure 20. Aircraft Climb, Cruise and Descent Model Profile

For the relatively short trip distances involved in the low-density arena it has been found that the cruise and descent phase can both be adequately combined as one long slow descent. Assuming constant rate of climb, climb speed, altitude to climb from ground level, and cruise speed, it can be shown that total trip time, or block time, t_{trip}, is

$$t_{trip} = \left[\frac{\Delta h}{ROC \bullet 60} \left(1 - \frac{V_{CL}}{V_C}\right) + t_{fixed}\right] + \frac{1}{V_C} \bullet X_{trip}$$

where

t_{fixed} = time to taxi, take off, land, maneuver - hours

Δh = altitude to climb from ground level - feet

ROC = rate of climb - feet per minute

V_{CL} = climb speed - miles per hour

V_C = cruise speed - miles per hour

X_{trip} = air trip distance - miles

or

$$t_{trip} = T_1 + T_2 \bullet X_{trip}$$

where T_1 and T_2 are constant quantities for any given aircraft and, therefore, t_{trip} is a linear function of X_{trip} according to this model.

The performance parameters shown in Table 23 were used initially to obtain aircraft block time versus trip distance. These values were the most representative that could be obtained from aircraft manufacturers specifications, trade journals, and any other sources available.

Table 23. Aircraft Performance Data

Aircraft	ROC (fpm)	Climb Speed (V_{CL}, mph)	Cruise Speed (V_C, mph)
Cessna 402B	1350	126	218
Beech 99A	1400	136	254
DHC-6	1150	102	192
Piper Aztec Turbo E	1450	115	224
Swearingen Metro	2200	150	286

A representative value of Δh was found to be 5000 feet after surveying the airport and terrain characteristics in the Arizona and West Virginia arenas. The value used for t_{fixed} to account for taxi, takeoff, and maneuver time was 0.2 hour.

When aircraft block time versus trip distance was computed, as outlined above, it did not compare well with some actual schedule data based on the Cessna 402B aircraft from Cochise Airlines. This is illustrated in Figure 21a. The explanation of the difference seems to be the effect of headwinds, waiting in pattern at destination, and allowance for increased values for t_{fixed} for higher trip distances which may singly or together combine to increase effective block time. Adequate allowances for these effects were not included in the model. It was found that by reducing the effective aircraft cruise velocity together with suitable adjustments made to t_{fixed} the appropriate variation of block time with trip distance was obtained. This approach resulted in the block times shown in Figure 21b which were used throughout the study.

3. AVIONICS

Advanced avionic equipment for commuter air carriers was developed based upon an analysis of available equipment and aircraft requirements. A summary of advanced avionic equipment by weight class is shown in Table 24.

Under light aircraft, avionic equipment costs are shown both for equipment that does and equipment that does not meet FAA Technical Service Orders (TSO).[53] This comparison illustrates the differences in cost between the least costly available equipment for general aviation use and equipment the commuter airlines must have to operate within controlled airspace and meet FAA operational requirements. Depending upon the type and location of airports less costly equipment may be utilized.

Optional equipment that may be necessary depending upon the nature of the routes served is also shown.

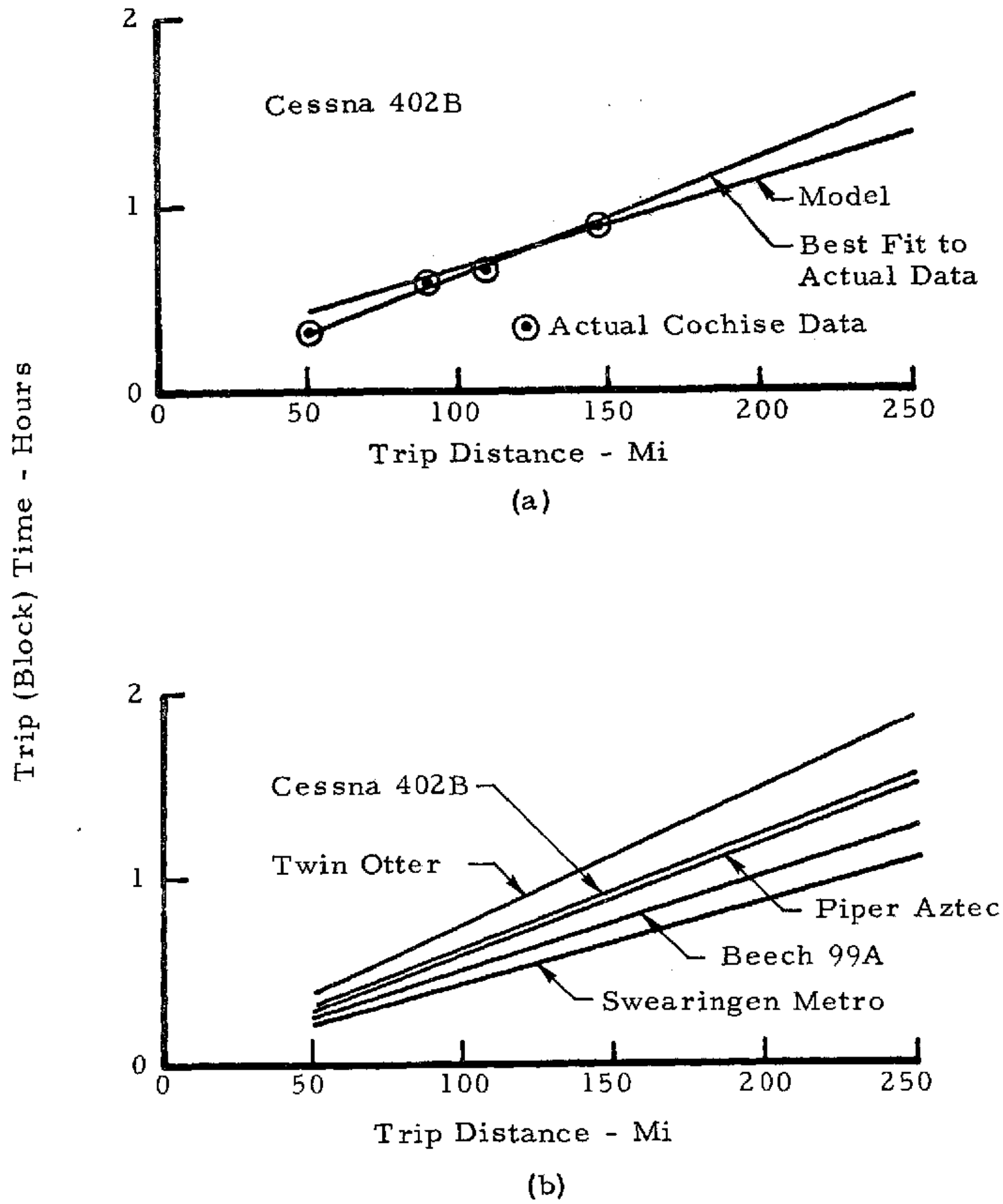

Figure 21. Block Time for Commuter Aircraft

Table 24. Advanced Avionic Systems--Small Aircraft (5-19 Passengers), Scheduled Airline Service

	General Aviation Type			Airline Type
	Light (Up to 6,499 lbs)		Medium	
	Non-TSO[1]	TSO[2]	(6,500 - 12,500 lbs)	(Over 12,500 lbs)
Avionic Equipment				
Dual VHF Communications, 720 Channel Capacity & Navigation (VOR/ILS) 200 Channel Capacity	$ 3,400	$ 5,800	$14,000	$ 25,200
ATC Transponder - 4096 Codes	600	1,200	2,200	4,800
Automatic Direction Finder	800	1,300	3,300	4,800
Distance Measuring Equipment	1,500	2,500	3,500	20,000 (2)
Autopilot	700	4,500	5,600	12,000
Area Navigation (VOR)	2,000	2,800	6,000	26,000
Flight Director/Horizontal Situation Indicator	3,000	6,000	12,000	25,000
Radio Altimeter	1,000	9,600	10,000	20,000 (2)
Emergency Locator Transmitter	150	300	500	--
Weather Radar	--	--	6,600	20,000
Collision Avoidance System/PWI	400	400	4,000	25,000
Intercommunication & Public Address	400	400	600	1,000
Total Avionic Equipment	$13,950	$34,800	$68,300	$183,800
CAB & FAA Regulations				
Economic Regulation (CAB)	298	298	298	298/Route Cert.
Operational Certification (FAA-FAR)	135	135	135	121
Aircraft Certification (FAR)	23	23	23	25

(1) Does Not Meet FAA Technical Service Order
(2) Meets FAA Technical Service Order

4. ECONOMICS

a. Flyaway Costs

Flyaway costs were estimated based on the latest published sales price plus allowances for optional and advanced avionics equipment. A summary of flyaway costs for various unpressurized and pressurized aircraft along with operational and operating cost data is shown in Table 25.

Typical optional equipment for light aircraft up to 6,499 pounds TOGW and for medium aircraft from 6,500 to 12,500 pounds TOGW was developed (Table 26). Except for extra fuel tanks and air conditioning, the equipment shown is believed to be required to meet safety and operational requirements. A deicing system, for example, has been included since most airlines experience bad weather conditions, particularly in mountainous areas, where operations could not be conducted without such equipment.

Advanced avionic equipment has been summarized by weight class and was shown in Table 24. Table 27 shows the minimum avionic system equipment necessary to operate within controlled airspace. Advanced systems in both capacity and types, such as the flight director/horizontal situation indicator and collision avoidance system/proximity warning indicator, have been included. It can also be seen that avionics equipment in aircraft over 12,500 pounds will approach the cost and complexity of equipment found in aircraft operated by the larger certificated air carriers.

b. Direct Operating Costs

Direct operating costs (DOC) of representative twin engine unpressurized and pressurized aircraft suitable for commuter air service were developed and categorized with flying operations, direct maintenance, and depreciation. A cost methodology for each DOC element was formulated utilizing manufacturer's estimates, surveys of commuter air carriers, NBAA reports, CAB aircraft operating costs, and trade journals. This is discussed in the following paragraphs.

Table 25. Aircraft Cost and Performance Comparison
Full Optional Equipment and Avionics

	Unpressurized				Pressurized
	Piston		Turboprop		Turboprop
	Cessna 402B	Piper Aztec Turbo E	Beech 99A	DeHavilland DHC-6-300	Swearingen Metro
Flyaway Cost (000)					
Basic Cost	$ 117	$ 80	$ 400	$ 495	$ 540
Optional Equipment	25	25	38	38	38
Avionics	35	35	68	68	68
	$ 177	$140	$ 506	$ 601	$ 646
Operational Data					
TOGW	6,300	5,200	10,400	12,500	12,500
Empty Weight	3,719	3,229	6,000	7,254	7,646
Max Cruise (MPH)	218	224	254	192	286
Fuel Consumption (Gal/Hr)	28.5	32.6	116.2	92.3	93.5
Crew Size	1	1	2	2	2
Passengers	9	5	15	19	19
Operating Cost Data					
Flight Crew (75 Hrs/Mo.)[1]					
Captain	$ 950	$ 950	$1,050	$1,050	$1,050
Co-Pilot			600	600	600
Fuel & Oil (¢/Gal)	.33¢	.33¢	.2625¢	.2625¢	.2625¢
Insurance	2%	2%	2%	2%	2%
Depreciation	8/20	8/20	8/20	8/20	8/20

[1] Plus Fringe Benefits (20%)

Table 26. Typical Optional Equipment--Small Aircraft (5-19 Passengers) Scheduled Airline Service

Optional Equipment	Light (Up to 6,499 lbs)	Medium (6,500-12,500 lbs)
Flight Instruments	$ 1,600	$ 2,600
Propeller Synchronization	1,700	2,500
Strobe and Beacon Lights	500	1,000
Oxygen System	1,000	1,200
Complete De-Icing System	10,000	14,000
Alternators	1,400	2,300
Fuel Tanks	2,200	3,000
Air Conditioning	6,000	10,000
Miscellaneous	600	1,000
	$25,000	$37,600

Table 27. Aircraft Cost and Performance Comparison--
Minimum Optional Equipment and Avionics

	Unpressurized				Pressurized
	Piston		Turboprop		Turboprop
Aircraft Flyaway Cost (000)	Cessna 402B	Piper Aztec Turbo E	Beech 99A	DeHavilland DHC-6-300	Swearingen Metro
Basic Cost	$ 117	$ 80	$ 400	$ 495	$ 540
Optional Equipment*	17	17	25	25	25
Avionics**	16	16	30	30	30
	$ 150	$ 113	$ 455	$ 550	$ 595

*Optional Equipment

Flight Instruments
Propeller Synchronization
Strobe & Beacon Lights
Oxygen System
Complete De-Icing System
Alternators

**Avionics Equipment

Dual VHF Communications
ATC Transponder
Automatic Direction Finder
Distance Measuring Equipment
Autopilot
Emergency Locator Transmitter
Collision Avoidance System/PW1
Intercommunications & Public Address

(1) Flying Operations

Monthly flight crew costs were developed for both captain and co-pilot based on a recent commuter airline pilot survey and reported airline costs. These costs are shown in Tables 28 through 31 in accordance with the size of the aircraft. In computing hourly costs, a flying time of 75 hours per month was used to reflect allowances for schedules, training, and station basing. Fringe benefits of 20% were added to account for various employee benefits.

Fuel and oil costs were estimated from reported commuter airline costs and represent a general composite of fuel costs from main bases and remote stations. These costs are shown in Tables 28 through 31.

Insurance costs of 2% per year are representative of both general aviation operations and commuter airlines for fixed wing aircraft.

(2) Direct Maintenance

Maintenance costs will vary widely with type of aircraft and engine and also between airlines with similar aircraft. Generally, maintenance costs reported by business operators are considerably higher than those outlined by the manufacturer. However, several commuter airlines also offer aircraft maintenance services in addition to their airline service and thereby achieve maintenance costs close to those estimated by the manufacturer. Therefore, the maintenance costs developed in this analysis were based on tbe assumption that the commuter air carrier will have this diversity of operation.

To estimate them on a consistent basis, maintenance costs by type of aircraft were developed as a function of empty weight. Figure 22 illustrates the direct maintenance cost per flying hour for regular and turbocharged piston aircraft. Figure 23 correspondingly shows the maintenance cost for pressurized aircraft.

For turboprop aircraft, estimates were developed for pressurized and unpressurized versions as illustrated in Figure 24. Unpressurized aircraft were further defined into fast and slow aircraft. As can be seen there is a significant difference between pressurized and slow unpressurized aircraft.

Table 28. Direct Operating Cost Per Flying Hour, Annual Utilization 2,000 Hours--Minimum Optional Equipment and Avionics

	Unpressurized				Pressurized
	Piston		Turboprop		Turboprop
	Piper Aztec Turbo E	Cessna 402B	Beech 99A	DeHavilland DHC 6-300	Swearingen Metro
Per Flying Hour					
Flying Operations					
Flight Crew	$ 15.20	$ 15.20	$ 26.40	$ 26.40	$ 26.40
Fuel & Oil	10.76	9.41	30.50	24.23	24.54
Insurance	1.13	1.50	4.55	5.50	5.95
Total Flying Operations	$ 27.09	$ 26.11	$ 61.45	$ 56.13	$ 56.59
Direct Maintenance	$ 8.80	$ 15.00	$ 29.00	$ 20.00	$ 50.00
Depreciation	$ 5.65	$ 7.50	$ 22.75	$ 27.50	$ 29.75
Total DOC Per Flying Hour	$ 41.54	$ 48.61	$113.20	$103.63	$136.34

Table 29. Direct Operating Cost Per Flying Hour, Annual Utilization 2,000 Hours--Full Optional Equipment and Avionics

	Unpressurized				Pressurized
	Piston		Turboprop		Turboprop
	Piper Aztec Turbo E	Cessna 402B	Beech 99A	DeHavilland DHC 6-300	Swearingen Metro
Per Flying Hour					
Flying Operations					
Flight Crew	$ 15.20	$ 15.20	$ 26.40	$ 26.40	$ 26.40
Fuel & Oil	10.76	9.41	30.50	24.23	24.34
Insurance	1.40	1.77	5.06	6.01	6.46
Total Flying Operations	$ 27.36	$ 26.38	$ 61.96	$ 56.64	$ 57.40
Direct Maintenance	$ 9.24	$ 15.75	$ 30.45	$ 21.00	$ 52.50
Depreciation	$ 7.00	$ 8.88	$ 25.30	$ 30.05	$ 32.30
Total DOC Per Flying Hour	$ 43.60	$ 51.01	$117.71	$107.69	$142.20

Table 30. Direct Operating Cost Per Flying Hour, Annual Utilization 3,000 Hours--Minimum Optional Equipment and Avionics

	Unpressurized				Pressurized
	Piston		Turboprop		
	Piper Aztec Turbo E	Cessna 402B	Beech 99A	DeHavilland DHC 6-300	Pressurized Turboprop Swearingen Metro
Per Flying Hour					
Flying Operations					
Flight Crew	$ 15.20	$ 15.20	$ 26.40	$ 26.40	$ 26.40
Fuel & Oil	10.76	9.41	30.50	24.23	24.34
Insurance	.75	1.00	3.03	3.67	3.97
Total Flying Operations	$ 26.71	$ 25.61	$ 59.93	$ 54.30	$ 54.91
Direct Maintenance	$ 8.80	$ 15.00	$ 29.00	$ 20.00	$ 50.00
Depreciation	$ 3.77	$ 5.00	$ 15.17	$ 18.33	$ 19.83
Total DOC Per Flying Hour	$ 39.28	$ 45.61	$104.10	$ 92.63	$124.74

Table 31. Direct Operating Cost Per Flying Hour, Annual Utilization 3, 000 Hours -- Full Optional Equipment and Avionics

	Unpressurized				Pressurized
	Piston		Turboprop		Turboprop
	Piper Aztec Turbo E	Cessna 402B	Beech 99A	DeHavilland DHC 6-300	Swearingen Metro
Per Flying Hour					
Flying Operations					
Flight Crew	$ 15.00	$ 15.20	$ 26.40	$ 26.40	$ 26.40
Fuel & Oil	10.76	9.41	30.50	24.23	24.54
Insurance	.93	1.18	3.37	4.01	4.31
Total Flying Operations	$ 26.89	$ 25.79	$ 60.27	$ 54.64	$ 55.25
Direct Maintenance	$ 9.24	$ 15.75	$ 30.45	$ 21.00	$ 52.50
Depreciation	$ 4.67	$ 5.92	$ 16.87	$ 20.03	$ 21.53
Total DOC Per Flying Hour	$ 40.80	$ 47.46	$107.59	$ 95.67	$129.28

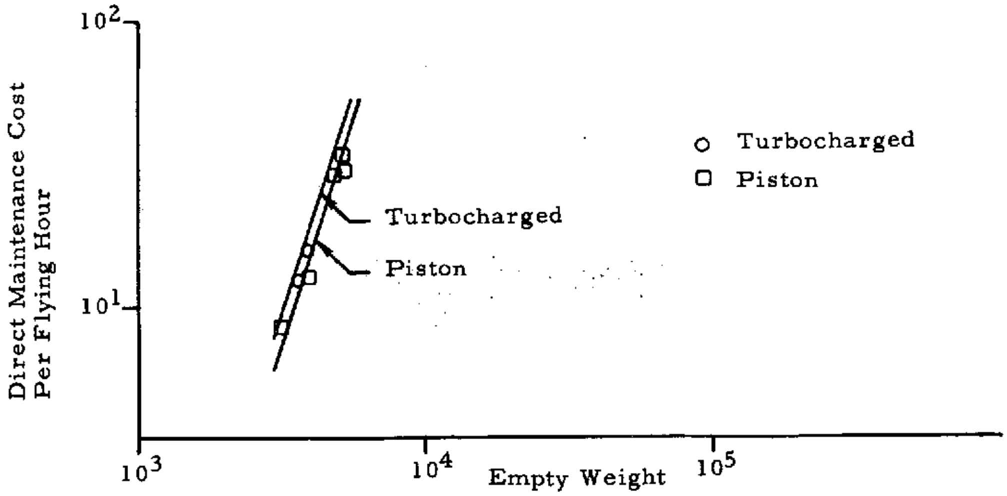

Figure 22. Piston Aircraft - Direct Maintenance Cost Per Flying Hour

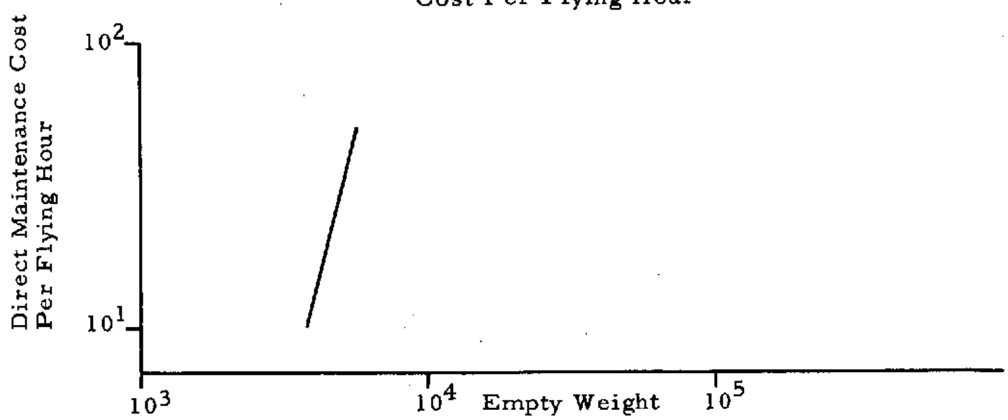

Figure 23. Pressurized Piston Aircraft-- Direct Maintenance Cost Per Flying Hour

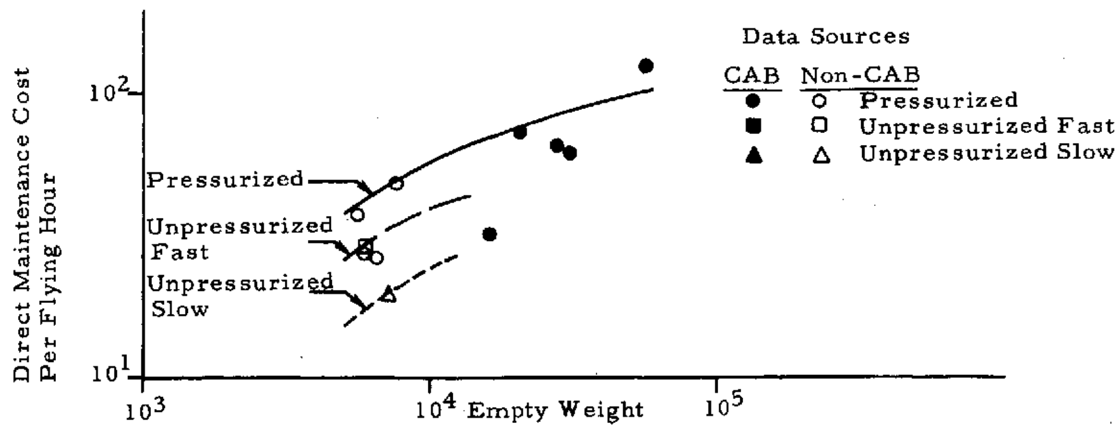

Figure 24. Turboprop Aircraft - Direct Maintenance Cost Per Flying Hour

Further differences in maintenance costs will occur depending upon the applicable FAA operational and aircraft certification regulations (Part 135/121 and Part 23/25).[54]

(3) Depreciation

An eight-year depreciation period with a 20% residual was used which is based on operator experience. The 10-year, 15% residual value guideline established by the CAB was judged to be applicable to larger turboprop aircraft and was therefore not used.

DOCs were computed for each aircraft for two flyaway costs. One cost represented an aircraft equipped with minimum optional equipment and avionics and the other an aircraft equipped with full optional equipment and avionics. DOCs per flying hour are summarized for each aircraft by DOC element for annual utilizations of 2,000 and 3,000 hours in Tables 28 through 31.

c. Indirect Operating Costs

(1) Overview

Indirect operating costs (IOCs) relate to general airline support and administrative operations. IOCs consist of passenger service, aircraft and traffic servicing, reservations and ticket sales, sales and advertising, general and administrative services, and depreciation on ground property.

IOCs vary widely with the type of airline operation and service provided by a commuter air carrier. This is a result of differences in number of aircraft operated, airports served, frequency of service, average stage length, and service provided on the aircraft and at terminals. Commuter air carriers serving rural markets were found to have lower IOC levels than carriers serving both rural and urban areas located near major metropolitan areas. IOC data utilized in this study was obtained from

a study conducted of commuter air carrier operating and traffic statistics which are contained in Section III. C. 4. e.

(2) Definition of IOCs

Commuter air carriers are not required to report the extensive financial and operating statistics that CAB certificated carriers must. As such, commuter air carriers do not maintain the complex statistical and financial accounting systems that are required of certificated carriers. To enable a consistent analysis of IOCs, commuter IOCs were defined and tabulated according to the following elements which are consistent with those of CAB certificated carriers.

(a) Passenger Service. Passenger service consists of activities contributing to the comfort, safety, and convenience of passengers while in flight and when flights are interrupted.

Commuter air carrier costs generally are passenger liability insurance, interrupted trip expense, food, and cabin attendants.

(b) Aircraft and Traffic Servicing. Aircraft and traffic servicing covers costs of ground personnel for handling and servicing aircraft, scheduling, landing and parking of aircraft, and rental of facilities.

Commuter air carrier costs generally are salaries and benefits of ground personnel or contracted services, landing fees, hangar rental, and station maintenance.

(c) Reservation and Ticket Sales. These are the costs of staffing and operating a reservation and ticket sales system and developing tariffs and operating schedules. However, for commuter air carriers costs are generally limited to salaries and benefits of reservationists, communications, commissions, space rental, and ticket supplies.

(d) Advertising and Publicity. Advertising and publicity is defined as the cost of promoting the use of air transportation and the carrier. However, for commuter air carriers costs are generally limited to advertising, salaries, and benefits of advertising personnel.

(e) General and Administrative. The general and administrative costs are of a general corporate nature such as accounting, purchasing, taxes, and management.

(f) Depreciation--Ground Property. Depreciation of property and equipment other than flight equipment.

(3) Characteristics of Commuter Air Carrier Indirect Operating Costs

(a) Passenger Service. Commuter aircraft are not equipped for other than simple beverage service. Most commuter airlines do not offer any food or beverage service, especially on those flights with short stage lengths. Although the size of current commuter aircraft does not require a cabin attendant, some airlines as a matter of service policy do provide one. Passenger liability insurance rates for commuter air carriers are considerably higher than for certificated carriers. Liability insurance costs for commuter airlines have been found to represent as much as 15% of a carrier's gross income compared to 1% for the trunks.[55] Commuter air carrier passenger liability rates tend to be based on the number of seats, whether occupied or not, while certificated carriers receive the benefits of a payload variation formula based on revenue passenger miles.

(b) Aircraft and Traffic Servicing. At airports with infrequent commuter airline service, part-time ground personnel may be used to service the aircraft or the commuter airline may have no personnel at a given airport

and contract all aircraft and traffic servicing to another air carrier. The larger air carriers typically have full-time personnel at each airport served. Landing fees, which are based on aircraft landing weight, are smaller for the lightweight commuter aircraft as is the required hangar space. The amount of baggage carried by the passengers per commuter flight is also small. Baggage may be handled by the co-pilot whose salary is a direct expense.

(c) Reservations and Ticket Sales. A commuter air carrier reservation and ticket sales system differs substantially from that of the certificated carrier in complexity and cost; it serves only one-tenth the number of passengers served by a typical local service airline. While some commuter air carriers are tied in to a certificated carrier's system, most are not. Low-density carriers typically have part-time counter personnel.

(d) Sales and Advertising. Commuter airline sales and advertising generally consists of small newspaper ads and short radio spots plus displays and schedules at various airports. Many commuter airlines use contacts with leading businesses to promote travel. Many also rely on travel agents and certificated carriers to route connecting passengers via their airline.

(e) General and Administrative Costs. Like any business, commuter airlines have a minimum level of general and administrative costs. Since they operate under minimum regulatory requirements many are able to keep these costs at a low level. The number of and salary of management personnel were also found to vary widely, with the costs increasing with the level of service provided.

(4) Model Formulation

Two IOC models were developed, one characteristic of rural air carriers and one typical of combined rural plus urban air carriers.

The first step in IOC model formulation was to organize and tabulate operating statistics and costs in a uniform manner as defined previously. The second step was to define a simple set of parameters that adequately describe key operating characteristics per departure. The parameters chosen were:

1. Available Seat Miles.
   This provides an indication of the capacity of the system.

2. Revenue Passenger Miles.
   This accounts for revenue sensitive costs such as liability insurance and traffic commissions.

3. Number of Passengers.
   The number of passengers provides an indication of the costs to process them--reservations, ticketing, baggage handling.

4. A Constant Cost.
   The constant cost covers generally constant or fixed costs per departure that are seen as landing fees, hangar rental, and terminal operations.

The individual cost elements of each commuter air carrier's IOCs were then allocated to each of these four parameters in accordance with the percent relationship of that cost to the parameter. The total cost and percent of cost for each parameter were then computed. By dividing each parameter by its average departure base, coefficients for each parameter were obtained.

The two resulting IOC formulas are shown in Table 32 and are computed on a cost/departure basis based on the sum of a constant cost per departure, number of passengers, available seat miles, and revenue passenger miles.

Table 32. Low-Density IOC Formula and Constants

$$\text{Cost/Departure} = (\text{Constant}) + \begin{pmatrix}\text{Constant x}\\ \text{Number of}\\ \text{Passengers}\end{pmatrix} + \begin{pmatrix}\text{Constant x}\\ \text{Available}\\ \text{Seat Miles}\end{pmatrix} + \begin{pmatrix}\text{Constant x}\\ \text{Revenue Pass.}\\ \text{Miles}\end{pmatrix}$$

Constants				
Rural Carriers	$ 4.13	$ 1.089	1.1184 ¢	.45594 ¢
Rural And High-Density Carriers	13.44	1.565	1.3574	.88004

An illustration of the resulting IOC as a function of stage length is shown in Figure 25. A comparison of operating statistics and indirect operating cost between rural and high-density carriers is shown in Table 33. The IOC formula for the rural carrier was then incorporated into the system economics and is the basis for all indirect operating costs developed in Arizona and West Virginia.

d. Return on Investment

A return on investment (ROI) analysis was incorporated into the system economics to provide a means to evaluate the profitablility of alternative aircraft and operational concepts. The ROI developed is reflective of an average that is representative of a number of years since an allowance for depreciation has been assumed in the ROI formulation. The ROI model that was used is based on current criteria established by the California Public Utilities Commission[56] which is shown in Table 34. As can be seen, the ROI rate base is sensitive to original aircraft cost,

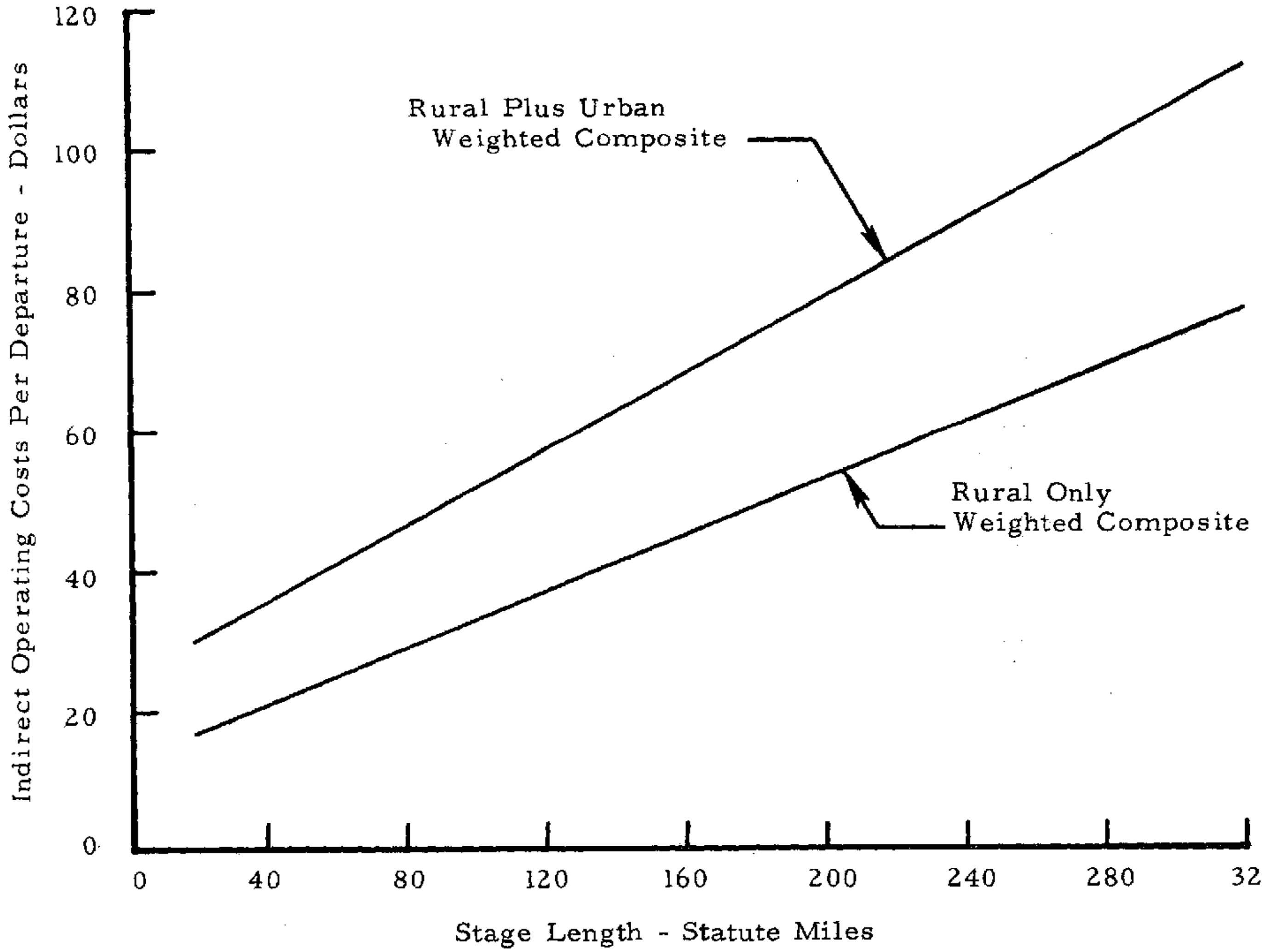

Figure 25. Indirect Operating Costs

Table 33. Commuter Air Carriers Comparison of Annual Operating Statistics and Indirect Operating Costs

	Weighted Composite	
	Urban Plus Rural	Rural
Annual Operating Statistics		
Number of Aircraft	4	3
Airports Served	8. 3	7
Number of Aircraft Per Airport Served	0. 48	0. 43
Aircraft Departure	14160	11580
Revenue Passengers (000)	51. 4	36. 4
System Load Factor	43. 2%	44. 1%
Per Aircraft		
Average Passenger Seats	14. 6	14
Average Block Speed (mph)	125	125
Average Passenger Trip Length (mi)	190	227
Average Stage Length	110	114
Revenue Passengers Per Aircraft Seat	880	867
Available Seat Miles (000)	5, 685	6, 160
Revenue Passenger Miles (000)	2, 456	2, 717
Utilization (hrs)	2, 500	2, 500
Indirect Operating Costs		
Per Departure	$51. 15	$32. 16
Per Passenger Handled	$14. 09	$10. 23

spares, depreciation, and other assets. The percent of original aircraft cost of 13.8% derived was applied to all original aircraft investment costs to determine the annual ROI required to earn a 10.5% profit.

Table 34. Return on Investment--California Public Utilities Commission Criteria (Cost in Thousands)

	Cal PUC Example
Original Aircraft Cost	$ 84,856.4
Spares and Flight Equipment	28,136.6
Less: Accrued Depreciation	14,374.0
Total Aircraft and Spares Cost	$ 98,619.0
Other Assets	$ 12,675.0
Rate Base	$111,294.0
Rate of Return	10.5%
Return on Investment	$ 11,685.9
Percent of Original Aircraft Cost	13.8%

The ROI per aircraft per year required to earn a 10.5% rate of return is shown in Table 35 for each of the basic aircraft used in the study. In terms of required operating profit per passenger seat for a 10.5% ROI, the Cessna 402B can be seen to be far below the other aircraft and this contributes towards its advantage over the Piper Aztec. Although the Twin Otter requires less operating profit than either the Beech 99A or Swearingen Metro, its low speed reduces its revenue capability to far below that of the other aircraft.

Table 35. Return on Investment Per Aircraft, Per Year to Earn 10.5%

	Full Optional Equipment and Avionics	Minimum Optional Equipment and Avionics	Per Passenger Seat
Piper Aztec Turbo E	$19,320	$15,594	$3,119
Cessna 402B	24,426	20,700	2,300
Beech 99A	69,828	62,790	4,198
DeHavilland DHC-6	82,938	75,900	3,994
Swearingen Metro	89,148	82,110	4,322

e. Study of Commuter Air Carrier Operating and Traffic Statistics, Costs, and Revenues

A study was conducted of commuter air carrier operating and traffic statistics, costs, and revenues to validate direct operating costs, develop an indirect operating cost model, and to examine the operating characteristics that impact on economic viability. Six commuter air carriers participated in this study. Their passenger and revenue passenger mile rank from an industry publication[57] are shown in Table 36.

Table 36. Commuter Air Carrier Ranks (Year Ended December 31, 1970)

Air Carrier	Passenger Rank	Revenue Passenger Miles Rank
A	6	4
B	14	20
C	24	11
D	34	22
E	35	19
F	over 50	over 50

From the data submitted by these airlines it was found that revenue passengers and passenger miles were sensitive to average stage and passenger trip length, number of departures, airports served, and aircraft operated. The general passenger capacity of aircraft operated was found to be similar. In addition to passenger revenues, all of the commuter airlines received various degrees of revenue from freight, express, and mail; charter; and miscellaneous services such as maintenance and pilot training.

To provide a means to evaluate the operating statistics and costs of commuter air carriers, a comparison of operational and cost statistics was made between a local service, California intrastate, and the average commuter air carrier. These comparisons are shown in Tables 37 and 38.

Annual operating and per aircraft statistics are listed in Table 37 which show the large differences in number and size of aircraft and passenger volume in terms of revenue passengers and passenger miles. The characteristics of low-density service are illustrated by the low 0.48 ratio of aircraft to airports served compared to the PSA high-density ratio of 3.13. Similarly, the relationship of departures per day per airport served also shows the smaller level of service provided by low-density carriers. The average commuter air carrier load factor was found to be identical to that of Allegheny and below that of PSA.

It can also be seen that the combination of a small number of seats, low block speed, and small average stage length combines to reduce the productivity of commuter aircraft, which is shown in terms of revenue passengers per aircraft seat and revenue passenger miles. For example, while the average size of Allegheny's aircraft is 5.4 times that of the commuters, it produces almost 10 times the seat miles. Correspondingly the faster PSA aircraft, which are 9.9 times in size that of the commuters, produces 23 times the available seat miles. Annual utilization of commuter carrier aircraft was found to be comparable to that of Allegheny and PSA. Some commuter air carriers reported over 3,000 hours of utilization.

Based on the total indirect operating costs and number of departures furnished by the commuter air carriers, the average indirect cost per departure and passenger handled is also shown. While the average cost per departure of $37.01 for a commuter air carrier is significantly less than that of Allegheny or PSA, the average cost per passenger handled of $9.40 is close to that of Allegheny and considerably higher than that of PSA.

Table 37. Comparison of Airline Operational Characteristics
Local Service, California Intrastate, and Average Commuter

ANNUAL OPERATING STATISTICS	ALLEGHENY	PSA	AVERAGE COMMUTER
Number of Aircraft	68	25	4
Airports Served	57	8	8.3
Number of Aircraft Per Airport Served	1.19	3.13	.48
Aircraft Departures	259,472	80,379	13,672
Aircraft Departures Per Airport Served	4,552	10,047	1,647
Revenue Passengers (000)	5,917	5,162	54
System Load Factor	43.2%	50.2%	43.2%
Departure Per Day Per Airport Service	12.47	27.5	4.6
PER AIRCRAFT			
Average Passenger Seats	79	144	14.6
Departures	3,816	3,215	3,418
Average Block-Block Speed (MPH)	213	330	125
Average Passenger Trip Length (Miles)	294	307	177
Average Stage Length (Miles)	190	228	110
Revenue Passengers Per Aircraft Seat	1,101	1,434	922
Available Seat Miles (000)	57,309	126,326	5,489
Revenue Passenger Miles (000)	24,748	63,416	2,370
Utilization (Hrs)	2,514	2,225	2,500
INDIRECT OPERATING COSTS			
Per Departure	$252.51	$306.37	$37.01
Per Passengers Handled	11.10	4.77	9.40

Table 38. Comparison of Annual Operating Costs and Fare Levels Local Service, California Intrastate and Average Commuter

	ALLEGHENY	PSA	AVERAGE COMMUTER
OPERATING COST (¢/ASM)			
Direct Operating Cost			
Flying Operations	1.199¢	.627¢	2.038¢
Direct Maintenance	.613¢	.312¢	.851¢
Depreciation	.189¢	.335¢	.792¢
Total Direct Operating Costs	2.001¢	1.274¢	3.681¢
Indirect Operating Cost			
Passenger Service	.262¢	.165¢	.210¢
Aircraft & Traffic Servicing	.849	.238	.743
Reservations & Sales	.355	.188	.708
General & Administrative	.182	.151	.615
Depreciation - Ground Property	.033	.029	.029
	1.681¢	.780¢	2.305¢
Total Operating Cost (¢/ASM)	3.682¢	2.054¢	5.986¢
Total Operating Cost (¢/RPM)*	7.816¢	3.998¢	11.713¢
Fare (¢/RPM)	8.427¢	4.601¢	12.408¢
Operating Profit (¢/RPM)	.611¢	.603¢	.695¢
OPERATING REVENUE (% of Total)			
Passenger	91.7%	97.7%	84.5%
Freight, Express, Mail	6.0	1.3	7.1
Charter	.2		3.8
Miscellaneous	1.1	1.0	4.6
Subsidy	1.0		
	100.0%	100.0%	100.0%

* Based on Load Factor and Percent Passenger Revenue

This comparison shows the inefficiencies in indirect operating costs associated with low-density service or service to many airports. Analysis of data of the commuter air carriers indicated that increases in revenue passengers were accompanied by significant increases in indirect operating costs.

Operating costs as a function of cents per available seat mile are shown in Table 38. Direct operating costs are believed to vary due to differences in flight crew pay, fuel and oil cost, maintenance practices, insurance valuations and rates, depreciation practices, and annual utilization.

Indirect operating costs are believed to vary depending upon liability insurance rates, aircraft and traffic servicing staffing at various airports, reservation and sales system, and administrative costs of operation including fully or partically allocated costs. The operating cost per revenue passenger mile is obtained by dividing the cost per available seat mile by the load factor. It can be readily seen that the seat mile costs of both Allegheny and PSA in virtually every direct and indirect cost category are below that of the commuter air carrier.

The differences in these costs are primarily the result of the productivity and efficiency of larger and faster aircraft and the operating economics that result from a large volume of traffic.

For example, in analyzing direct operating costs, the flight crew cost of the two-man crew of PSA is approximately $83 per flying hour compared to $27 for an average commuter airline two-man crew. A major airline pays approximately 13¢ per gallon for fuel compared to 25¢ per gallon for an average commuter airline. Hull insurance costs for a major airline are approximately 1% of aircraft value compared to 2% for commuter air carriers. A major air carrier also depreciates an aircraft over a longer period.

In analyzing indirect operating costs, although commuter airlines generally do not incur stewardess costs, the costs of passenger liability insurance are considerably higher than that of major carriers per revenue passenger mile. Similarly, it can be seen that aircraft and traffic servicing, reservations and sales, and general and administrative costs tend to be relatively fixed in nature and are not extremely sensitive to small variations in aircraft size. Therefore, an airline with a high productivity base will show correspondingly lower seat mile costs.

The total operating costs of the composite commuter air carrier were calculated to be 11.713¢ per revenue passenger mile. While the average fare per revenue passenger mile of 12.408¢ yielded an operating profit of 0.695¢, a fare of at least 14.292¢ per revenue passenger mile would be required to earn a rate of return on investment of 10.5%. Commuter air lines can be seen to require a significant higher fare level for economic viability compared to a local service carrier.

For a commuter air carrier to achieve lower seat mile operating costs which could lower fares there would have to be significant advances in aircraft performance and economics in airline operations. Faster, easily maintained, and moderately priced aircraft offering improved ride qualities would be a major step. Pooling of fuel purchases and hull and liability insurance could lower existing rates. Establishing single carrier aircraft and traffic servicing at airports used by more than one carrier could lower these costs. Sharing a reservation and ticketing system could lower reservation and sales expenses. Centralizing ticketing collection at major hubs could eliminate such expenses at many small intermediate stops. Such ticketing is used in limousine service at San Francisco International Airport and is common in India's railway system. It should, however, be recognized that in order for commuter airlines to improve equipment and operational practices their financial resources and routes need to be considerably strengthened.

5. AIRCRAFT UTILIZATION

For purposes of scheduling and for computing realistic direct operating costs there is a practical upper limit on aircraft utilization (actual engine on use per year) that cannot be exceeded. It is generally considered that 3,000 hours per year is pushing that upper limit based upon operating statistics of domestic airlines. To achieve 3,000 hours would require an aircraft to be operating for a total of about 8 hours per day for 365 days a year and that does not include ground or engine off time.

However, it is not unrealistic for commuter airlines to approach or even exceed 3,000 hours per year in normal operations (due to higher turnaround frequencies achievable, among other things). Shown in Tables 39 and 40 are the operating schedules of Cochise Airlines in Arizona and Allegheny Commuter Airlines in West Virginia. Both were obtained in the last quarter of 1971 and correspond to 2,739 and 3,358 hours of utilization respectively.

Based on this data it was decided to use 3,000 hours as the nominal upper limit in utilization for this study. In particular, when 3,000 hours was reached in any route analyzed, the fleet size was increased to accommodate it. Also, direct operating costs used throughout the analysis were always based on utilization rates of 3,000 hours per year or less.

Table 39. Cochise Airlines Schedule
4th Quarter 1971

To	From	Depart	Arrive	Flight No.	Service
Douglas	Ft. Huachuca	12:20 P	12:40 P	40	Daily
		6:20 P	6:40 P	550	XSa, Su
	Phoenix	10:40 A	12:40 P	40	Daily
	Tucson	5:20 A	5:55 A	520	Daily
		11:50 A	12:40 P	40	Daily
		5:50 P	6:40 P	550	XSa, Su
Ft. Huachuca	Douglas	6:05 A	6:25 A	605	Daily
		12:55 P	1:15 P	55	Daily
		6:55 P	7:15 P	655	XSa, Su
	Phoenix	10:40 A	12:10 P	40	Daily
	Tucson	11:50 A	12:10 P	40	Daily
		5:50 P	6:10 P	550	XSa, Su
Lake Havasu City	Phoenix	8:05 A	9:00 A	805	Daily
Phoenix	Douglas	6:05 A	7:45 A	605	Daily
		12:55 P	2:35 P	55	XSa, Su
	Ft. Huachuca	6:35 A	7:45 A	605	Daily
		1:25 P	2:35 P	55	XSa, Su
	Lake Havasu City	9:20 A	10:15 A	920	Daily
	Tucson	7:05 A	7:45 A	605	Daily
		1:55 P	2:35 P	55	XSa, Su
Tucson	Douglas	6:05 A	6:55 A	605	Daily
		12:55 P	1:45 P	55	Daily
		6:55 P	7:45 P	655	XSa, Su
	Ft. Huachuca	6:35 A	6:55 A	605	Daily
		1:25 P	1:45 P	55	Daily
		7:25 P	7:45 P	655	XSa, Su
	Phoenix	10:40 A	11:20 A	40	Daily
		5:00 P	5:40 P	500	XSa, Su

Equipment: Cessna 402
Total Utilization: 2739 hours/year

Table 40. Allegheny Commuter Airlines Schedule
4th Quarter 1971

Flight		30	32	34	36	40	190
Frequency		ExSu	ExSu	ExSa	ExSa	ExSa	Sa Only
Equipment		B-99	B-99	B-99	B-99	B-99	B-99
Charleston	lv		1045	1505			1505
Elkins	ar		1125	1545			1545
Elkins	lv		1135	1550			1550
Wash.,D.C.	ar		1235				
Wash.,D.C.	lv						
Clarksburg	ar			1610			1610
Clarksburg	lv	0625		1620			1620
Morgantown	ar	0640					1640
Morgantown	lv	0645			1755	1930	1645
Pittsburgh	ar	0725		1700	1825	1955	1715

Flight		31	80	35	37	45	191	38
Frequency		ExSu	Daily	ExSa	ExSa	ExSa	Sa Only	Su Only
Equipment		B-99	B-99	B-99	B-99	B-99	B-99	B-99
Pittsburgh	lv	0830		1720	1845	2100	1845	
Morgantown	ar	0900		1745	1910	2125	1910	
Morgantown	lv	0910				2135	1915	
Clarksburg	ar					2155	1935	
Clarksburg	lv							1105
Elkins	ar	0935						1125
Elkins	lv	0940						1135
Wash.,D.C.	ar							1235
Wash.,D.C.	lv		1255					
Elkins	ar		1400					
Elkins	lv		1405					
Charleston	ar	1020	1445					

Total Utilization: 3358 hours/year

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IV. RESULTS

A. REPRESENTATIVE DEMAND MATCHING RESULTS

1. NONSTOP ROUTES

In this section, actual detailed demand matching results for each of the five candidate aircraft and for seven of the 34 nonstop city pairs analyzed are shown. These city pairs, summarized in Table 41 below, are representative of the most typical situations encountered.

Table 41. Representative Arizona and West Virginia City Pairs Analyzed for Nonstop Air Service

	Nonstop Route Type	Has Major Air Hub	Has Major Trading Center	Can Support Viable Nonstop Air Service Independently
Phoenix-Grand Canyon	A	Yes	Yes	Yes
Phoenix-Clifton	A	Yes	Yes	Yes/No
Phoenix-Ft. Huachuca	A	Yes	Yes	Yes/No
Phoenix-Willcox	A	Yes	Yes	No
Las Vegas-Kingman	B	Yes	No	No
Charleston-Bluefield	B	No	Yes	No
Parkersburg-Morgantown	C	No	No	No

In addition, the optimum demand matching case for each of 34 Arizona and West Virginia city pairs and all five candidate aircraft have also been summarized in this section.

2. SCHEDULED STOP-ON-DEMAND ROUTES

Besides the nonstop route analysis, demand matching results are shown for a "scheduled stop-on-demand" or modified "dial-a-plane" route concept discussed in Section II-C. Two nonstop city pairs from Table 41 were selected for this example. Phoenix-Ft. Huachuca, which was profitable for the nonstop service, was the nominal service path and Willcox was chosen as the demand stop because by itself it cannot support nonstop air service to Phoenix at a profit. However, it will be shown later that the Phoenix-Ft. Huachuca-Willcox combination can support viable air service and provide the same or greater return on investment as the Phoenix-Ft. Huachuca pair did by itself.

3. EXPLANATION OF DEMAND MATCHING RESULTS

The nonstop service demand matching results that follow are presented in the form shown in Figure 26. The upper graph has a family of curves showing yearly profit or loss (above or below a fair ROI of 10.5%) versus scheduled fare. Each curve in the family corresponds to one set of values for frequency of service, round trips per day, and fleet size as indicated. Aircraft utilization corresponding to the indicated frequency of service is also shown. The lower graph has a similar family of curves showing predicted daily air travel demand for the same conditions. Starting at two round trips per day per aircraft and a fleet size of one, the air demand and profit or loss is determined as a function of scheduled fare. As the air demand increases to the point corresponding to a load factor of 0.75, the frequency of service is increased by one additional round trip and a new set of curves is generated. This is indicated in the figure by the arrows. As the frequency of service reaches the point that aircraft utilization is 3,000 hours per year the fleet size is increased by one aircraft and a new set of curves is again generated. This process is continued until the somewhat arbitrary limit of a fleet size of

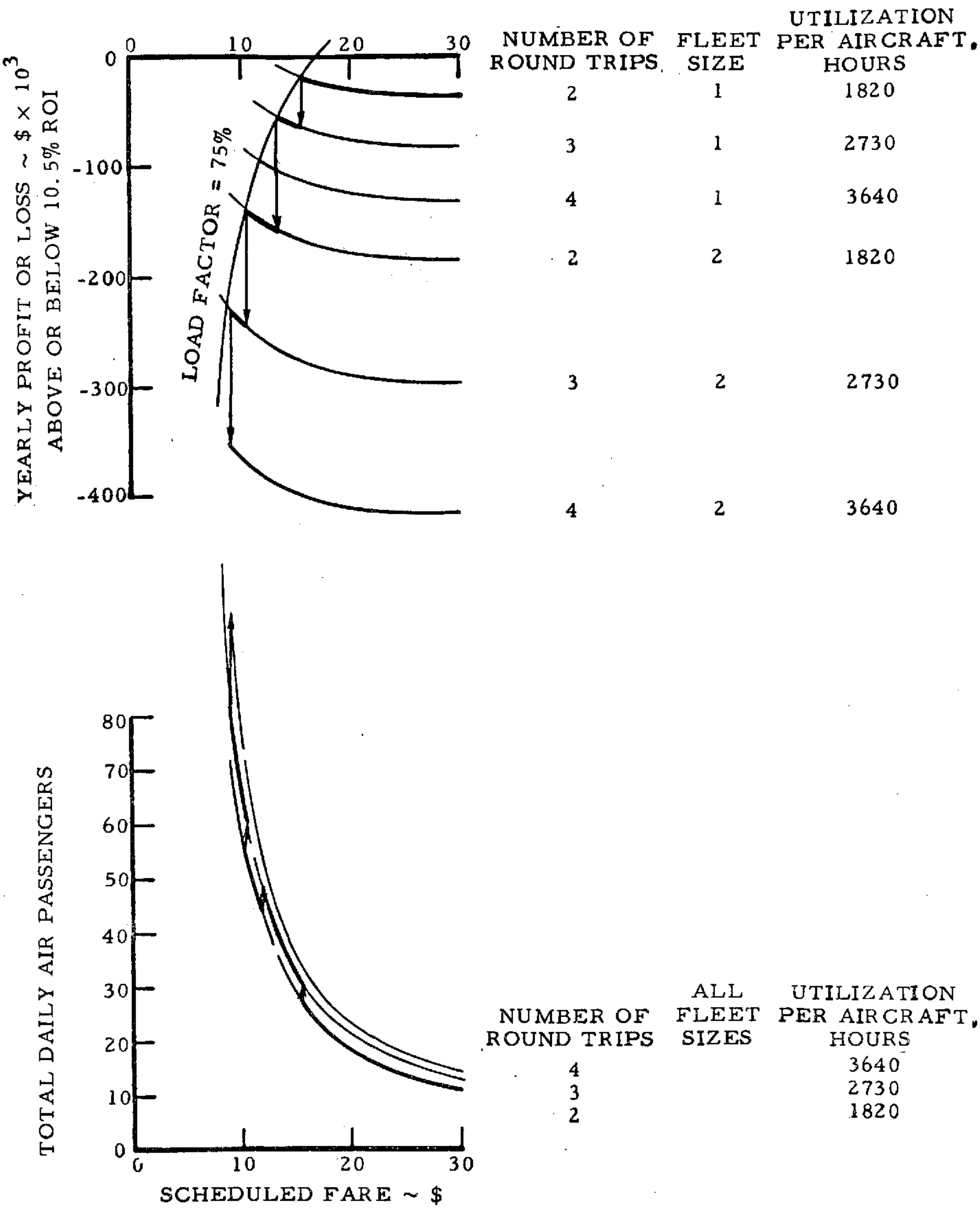


Figure 26. Demand Matching Output

four is reached. The result then has the shape of the broken curves connected by the arrows as illustrated in Figure 26. Since this figure is for illustration purposes, the curves have not been extended to the fleet size of four case because of space considerations.

4. SENSITIVITY STUDIES

Sensitivity studies were performed to assess the changes in system economics resulting from variations in aircraft performance and operating costs. Four sensitivity studies were performed:

1. Average cruise speed was increased by 50 mph.
2. Annual utilization was decreased 500 hours.
3. Direct operating costs were increased 10%.
4. Indirect operating costs were decreased 10%.

A review of the changes in the detailed cost elements from the sensitivity runs will permit the assessment of those aircraft and operational development areas most favorable for viable rural air service. The sensitivity results are discussed in Section IV-C.

5. NONSTOP CITY PAIR RESULTS

The trend line shown for each aircraft indicates the annual profit or loss above or below a 10.5% rate of return as a function of fleet size, number of trips per day, distance, air fare, and number of daily passengers carried. Since the operating characteristics and costs of each aircraft differ, each city pair analyzed varies in economic viability. Generally, city pairs with small demand cannot be economically served by 15-20 passenger aircraft nor can cities with larger demand be effectively served by 5-9 passenger aircraft. Thus, the seven examples listed in Table 41 were selected to discuss the economic viability of various types of nonstop rural routes. The routes will be discussed in the order of economic viability, with the most viable route discussed first.

The Phoenix-Grand Canyon Type A nonstop route, Figure 27, typifies the high-demand rural route where all five aircraft selected would be profitable.

1. The five-passenger Piper Aztec requires a fleet size of four to handle the daily passenger demand and is considered too small for this route, so is not shown on the curve.
2. The nine-passenger Cessna 402B, although not shown on the curve, is considered acceptable for this route. However, its acceptability requires a fleet size of three and three round trips per day per aircraft with each aircraft carrying 122 passengers per day, giving a 14.5% return on investment.

The three aircraft shown are compared for a fleet size of one and all three aircraft are acceptable. The 19-passenger 300-mph Swearingen is the most acceptable for this route (i.e., carries the most passengers, offers the lowest fare, and still achieves greater than 10.5% return of the investment). It has a 40-mph speed advantage over the Beech 99A, allowing one additional round trip per day, and it can also carry four more passengers than the Beech 99A. The Swearingen has the same number of seats and approximately the same costs as the Twin Otter but flies 100-mph faster. This allows more round trips per day carrying a greater number of passengers at a lower fare.

The next two Type A nonstop routes, Phoenix-Clifton and Phoenix-Ft. Huachuca, Figures 28 and 29, are good examples of the importance of matching the smaller aircraft capacities to the lower demand routes. Both routes show:

1. Only the Piper Aztec and Cessna 402B can operate profitably on this route. The Cessna can operate at a $15.00 fare and carry 37 passengers at approximately a 10.5% ROI. The Piper Aztec would require a $20 fare and carry only 30 passengers.
2. The Beech 99A, Swearingen, and Twin Otter are too large and costly to operate in relation to the daily demand.

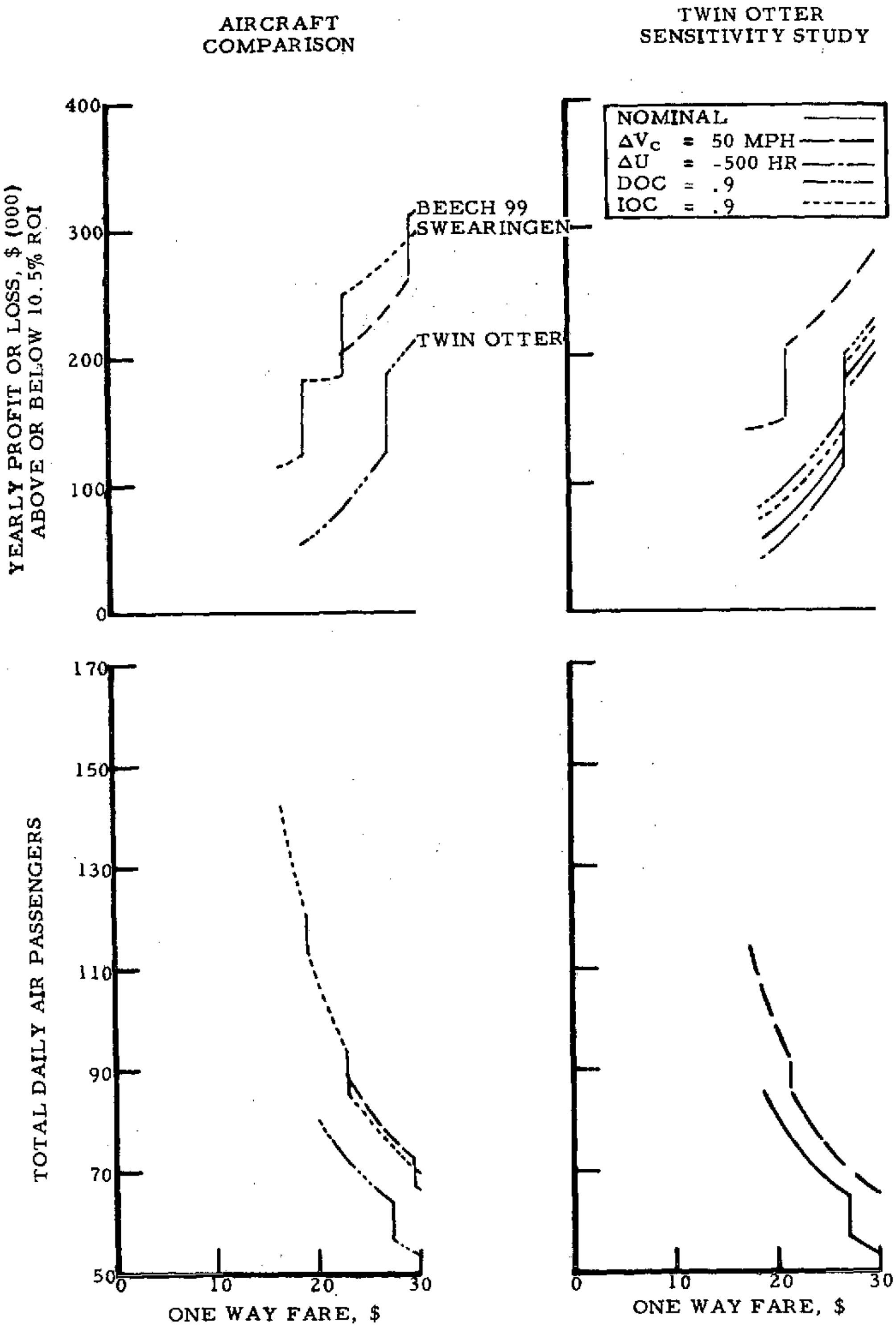


Figure 27. Phoenix-Grand Canyon

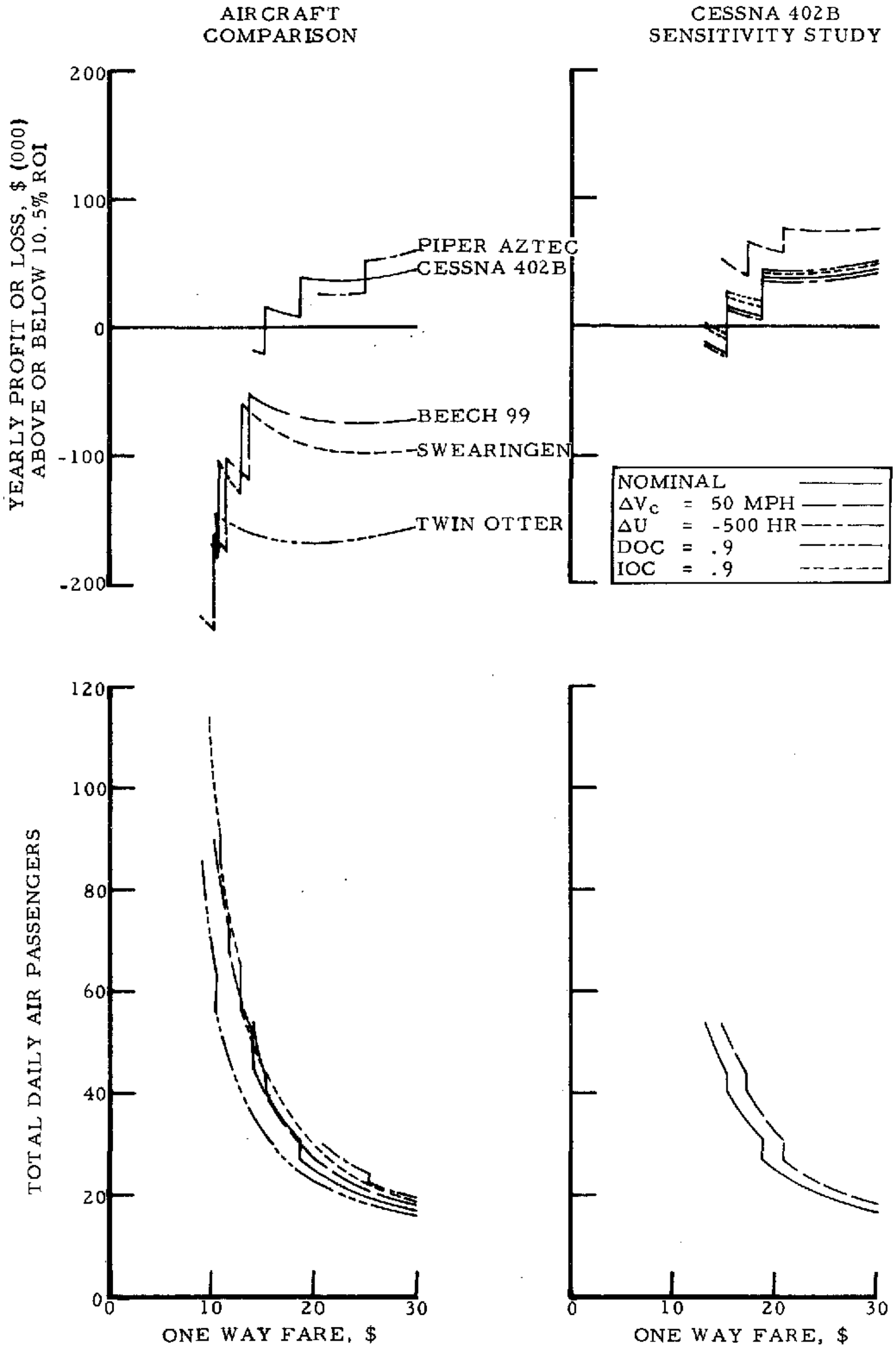


Figure 28. Phoenix-Clifton

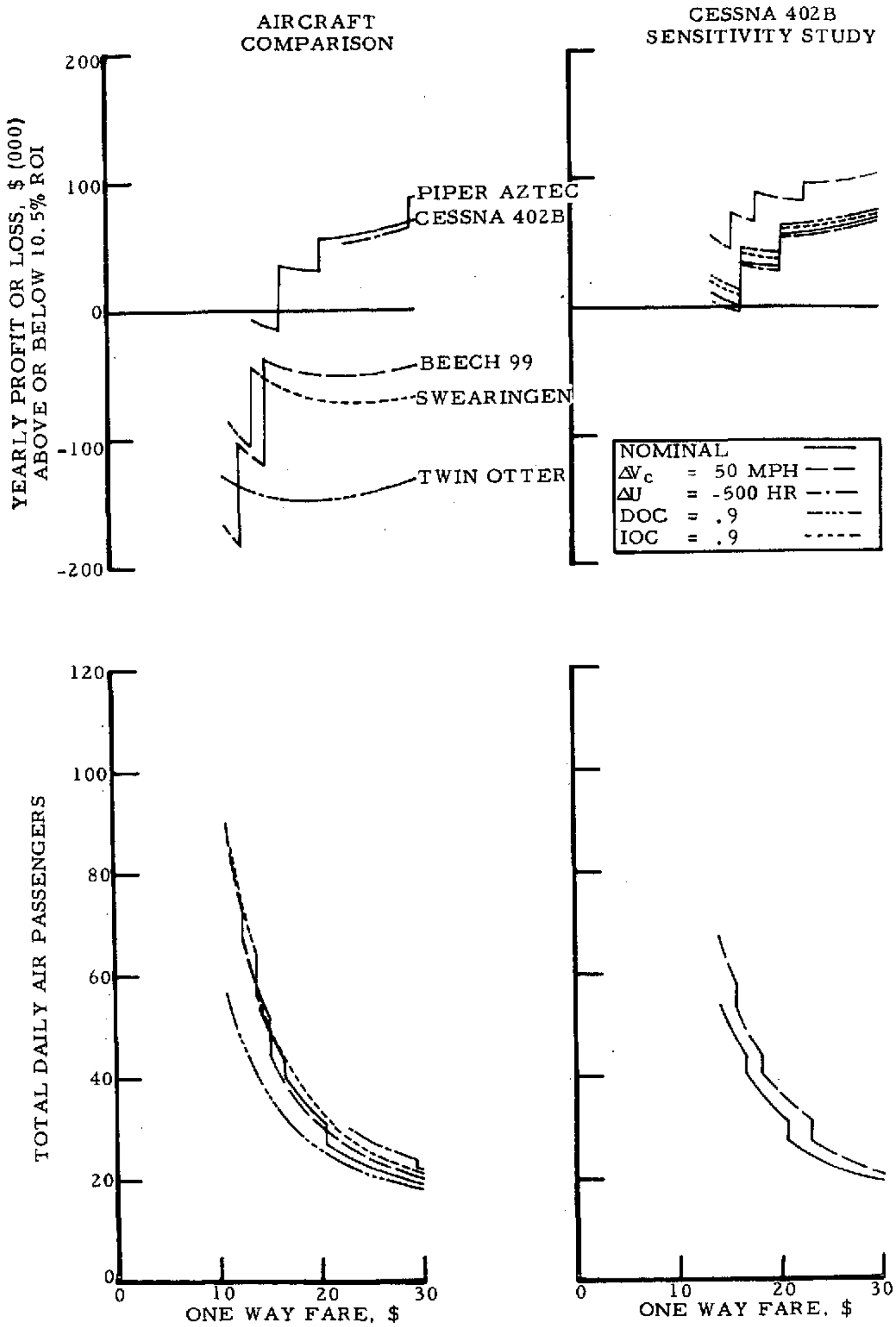


Figure 29. Phoenix-Ft. Huachuca

The Phoenix-Willcox Type A nonstop route (Figure 30) is a route where none of the five aircraft examined are viable. (For clarity the Piper Aztec was omitted from the figure.) This route also shows how an improvement in aircraft performance can make the route profitable. With a 50-mph increase in cruise speed of the Cessna 402B the route becomes viable.

The Las Vegas-Kingman and the Charleston-Bluefield routes (Figures 31 and 32) are two of the Type B routes where the travel demand is too low to provide nonstop service with existing aircraft. The sensitivity studies indicate that the routes probably require a major technological breakthrough to increase the aircraft speed with little or no increase in cost or that the route must be combined with some other route as a "scheduled stop-on-demand."

The Parkersburg-Morgantown Type C nonstop route (Figure 33) is similar to the two Type B routes just discussed. The travel demand is so low that even with major aircraft innovations it would be unlikely that the route could become viable. Analysis of multistop routes should be considered for this type of city pair.

6. "STOP-ON-DEMAND" RESULTS

Demand matching results from the "scheduled stop-on-demand" or modified "dial-a-plane" example are shown in Figures 34 and 35 for four of the five candidate aircraft considered. For this comparison a fleet size of one and a frequency of service of two round trips per day per aircraft was used. Under these conditions the Piper Aztec Turbo E capacity was too small to satisfy the demand generated by this routing concept and so it could not be included in the comparison.

The approach used here was to consider under what conditions, if any, an aircraft nominally carrying nonstop passengers between Phoenix

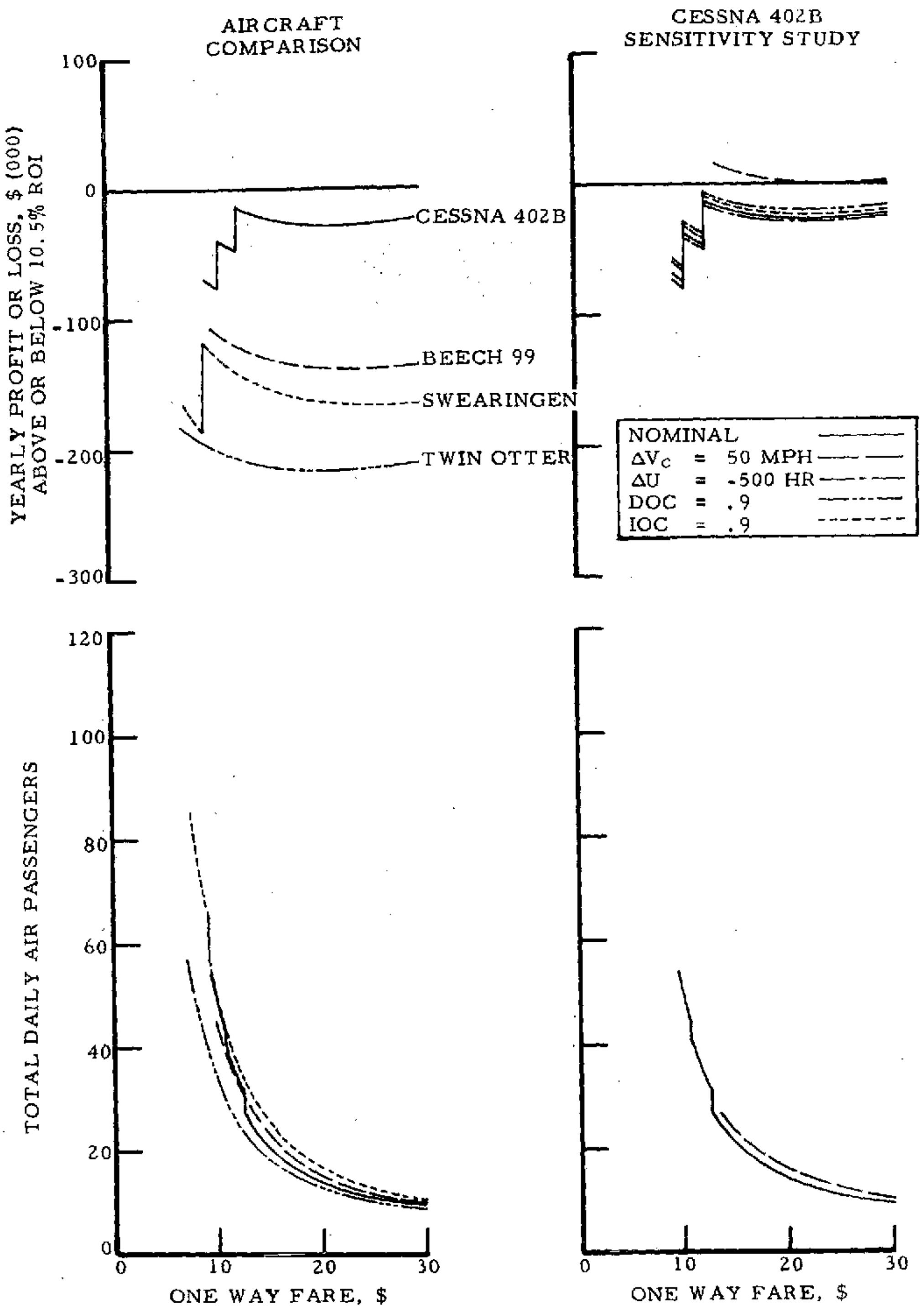


Figure 30. Phoenix-Willcox

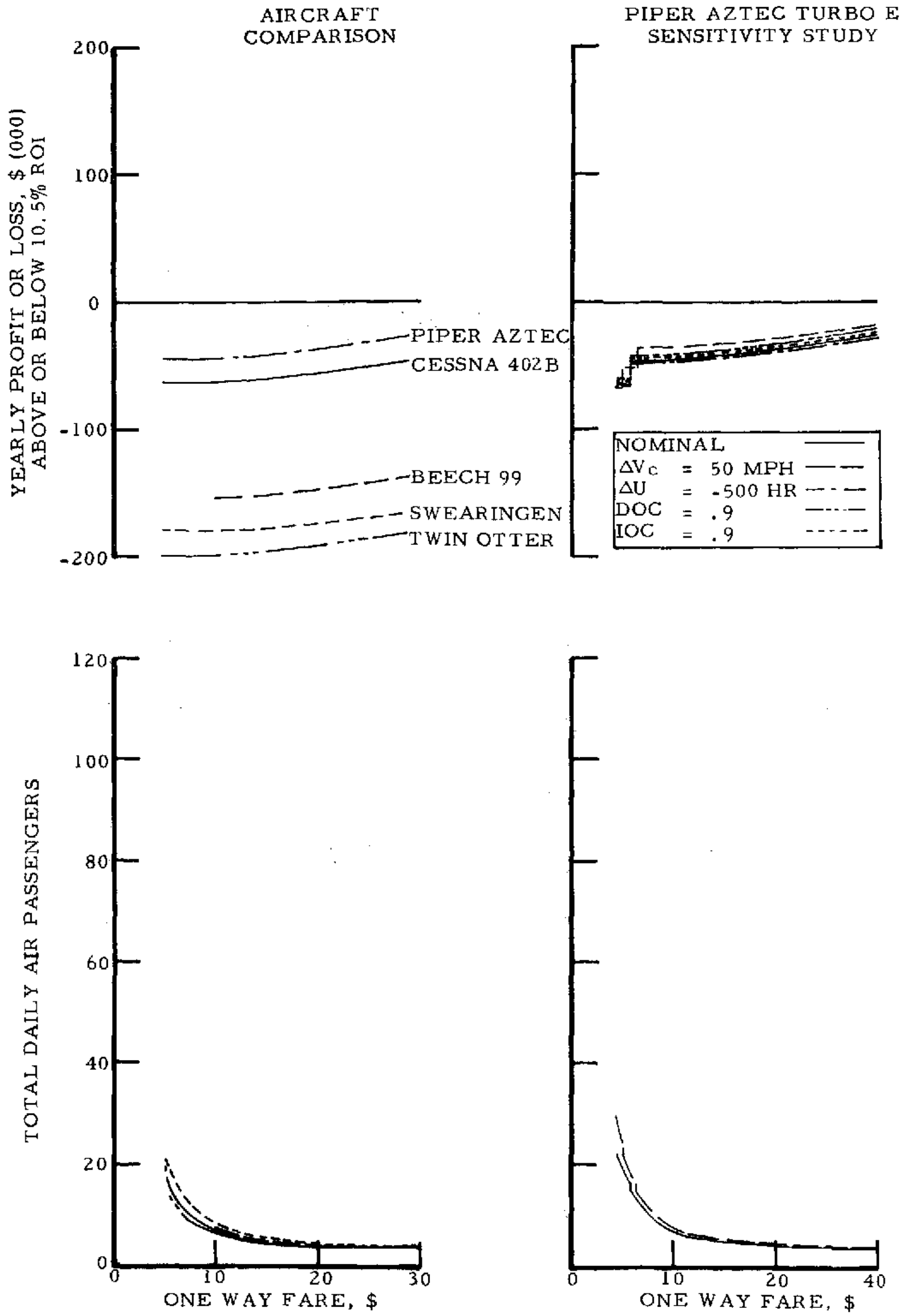


Figure 31. Las Vegas-Kingman

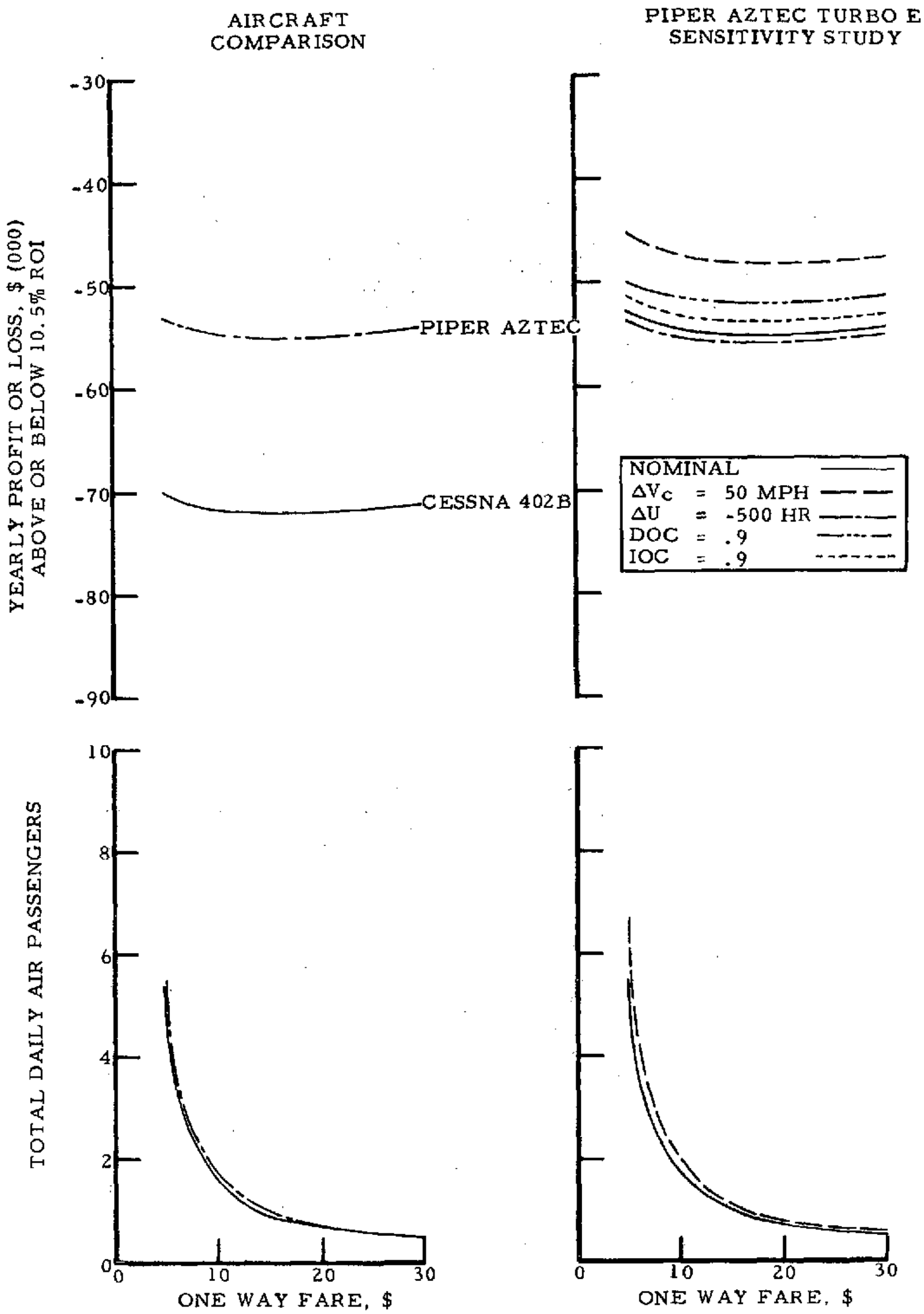


Figure 32. Charleston-Bluefield

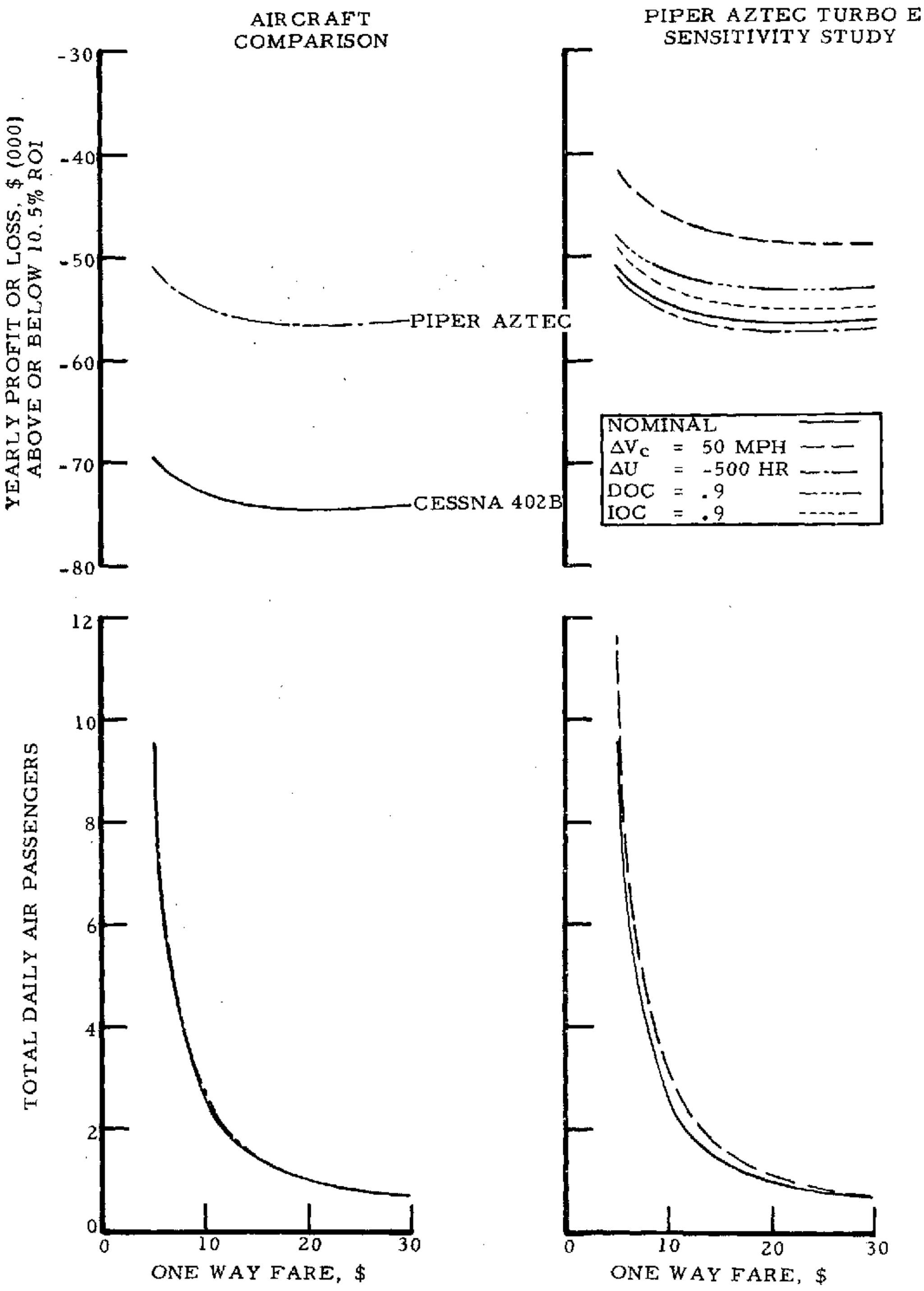
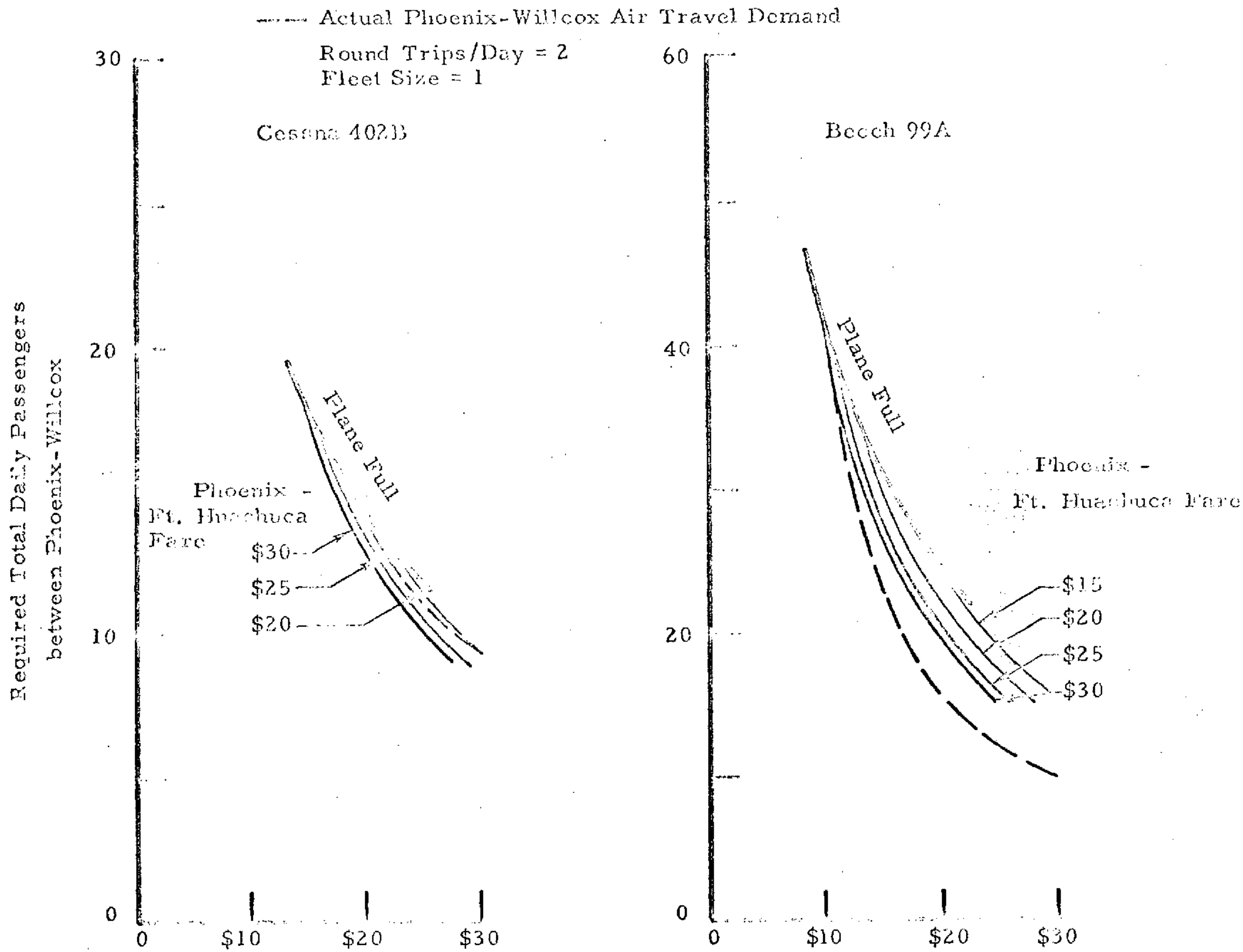


Figure 33. Parkersburg-Morgantown

Willcox, Arizona is "Stop-on-Demand" City



Scheduled Fare: Phoenix-Willcox, Arizona

Figure 34. "Scheduled Stop-on-Demand" Results (Cessna 402B and Beech 99A)

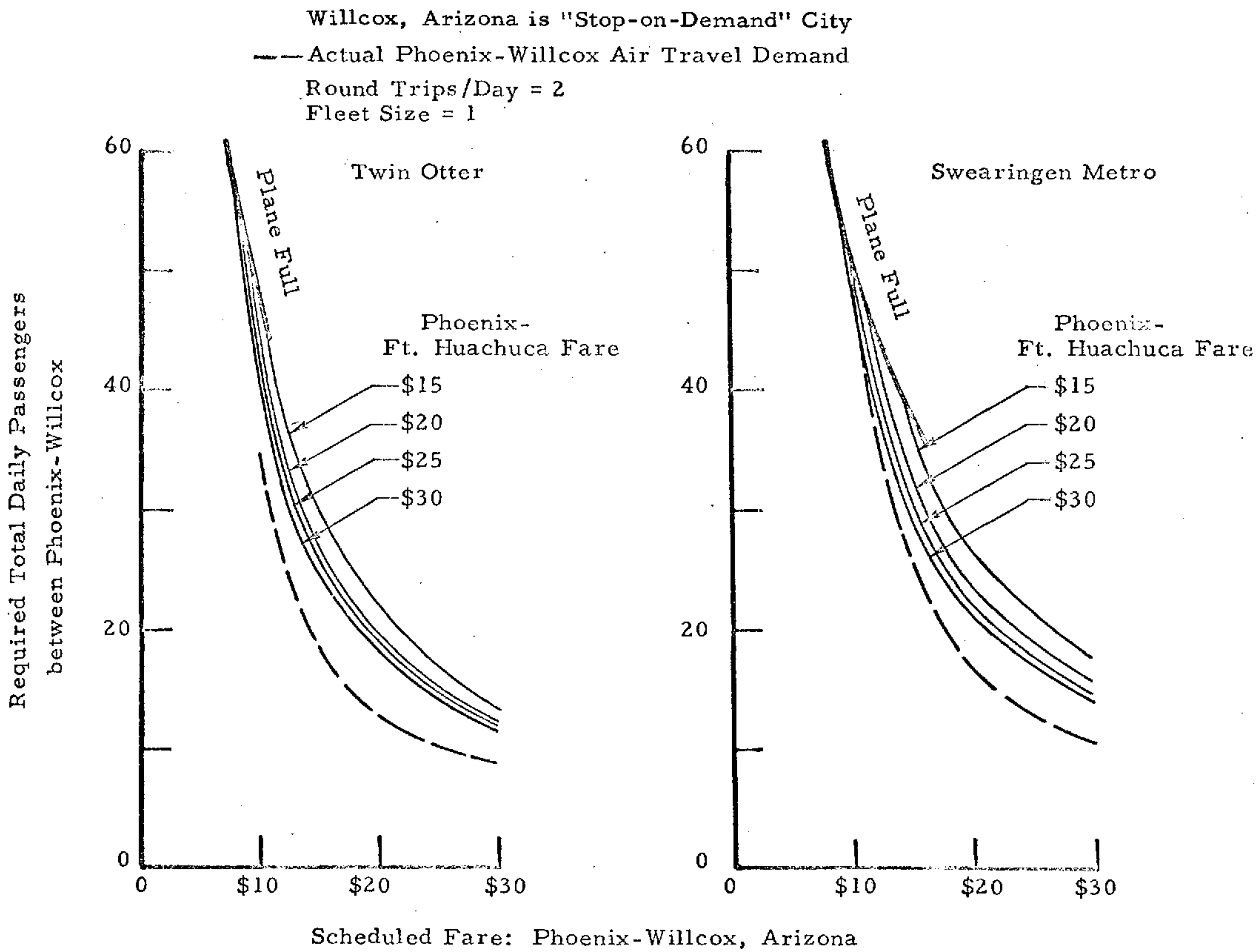


Figure 35. "Scheduled Stop-on-Demand" Results
(Twin Otter and Swearingen Metro)

and Ft. Huachuca could be diverted to Willcox to accommodate Phoenix-Willcox passenger demand and operate at the same profit as the nominal Phoenix-Ft. Huachuca nonstop route. This would involve questions such as:

1. The number of passengers and fare required at Willcox to maintain the same profit as from Phoenix-Ft. Huachuca route.
2. The number of Willcox passengers willing to pay the required fare.
3. The number of Ft. Huachuca passengers that would be lost to other modes of travel because of increased trip time due to the extra Willcox stop, and the effect of that loss of revenue.
4. The possibility of reducing the fare to Ft. Huachuca passengers to compensate for the increased time penalty and its effect on the overall cost picture.

Shown in Figures 34 and 35 (as the solid thin lines) is the required total daily air passengers as a function of Willcox fare (on the abscissa) for different values of Ft. Huachuca fare as indicated. These results are directed at answering question 1 above. The solid thick curve is the boundary of total Ft. Huachuca and Willcox to Phoenix passengers which fill the aircraft to full capacity for two round trips a day. Shown as the dashed line is the number of Willcox passengers that are willing to pay the prescribed fare as obtained from the Modal Split Simulation Program.

What is immediately apparent is that the Willcox passengers required to make the "demand stop" payoff are more than the number that are willing to pay for every candidate aircraft except the Cessna 402B. In this latter instance there are combinations which work; however, there are some interesting twists. For example, the Ft. Huachuca passengers will be paying fares ranging around \$25 to \$30 on the "scheduled stop-on-demand" route to Phoenix. For the nonstop route concept the fare would have been just under \$20. What is interesting is that this example "stop-on-demand" case will not work if the nonstop fare is charged to the Ft. Huachuca passengers, much less an even lower one. This has the effect of

Table 43. Analysis of Operational and Economic Characteristics--Piper Aztec Turbo E

City Pair	Fleet Size	One-Way Fare, $	Total Daily Round Trips	Total Daily Air Passengers	Load Factor	Utilization Factor	Return On Investment, %
Phoenix-AJO	1	15.50	5	37	.74	.66	46.9%
Clifton	1	21.00	4	30	.75	.96	27.3
Douglas	1	23.00	2	15	.75	.58	13.9
Flagstaff	(Requires Fleet Size > 4)						
Ft. Huachuca	1	23.00	4	30	.75	.94	46.2
Globe	(Requires Fleet Size > 4)						
Grand Canyon	4	27.80	2	60	.75	.51	33.7
Holbrook	2	17.70	3	46	.77	.64	12.2
Kingman	1	22.50	3	22	.73	.74	26.7
Lk. Havasu City	2	19.30	3	45	.75	.65	17.2
Nogales	2	23.70	2	30	.75	.46	26.0
Page	1	26.00	2	15	.75	.71	7.7
Parker	1	15.00	3	22	.73	.74	- .3
Prescott	2	12.30	5	75	.75	.66	16.6
Safford	2	18.70	4	60	.75	.86	24.0
San Manual	1	16.00	6	45	.75	.87	50.9
Show-Low	3	21.40	5	113	.75	.94	68.6
Springerville	2	24.30	2	30	.75	.48	25.6
Willcox	1	19.50	2	15	.75	.44	12.5
Winslow	1	16.00	5	37	.74	.98	12.5
Tucson -Ft. Huachuca	1	9.70	2	15	.75	.16	7.1
Douglas	1	11.30	2	15	.75	.27	2.4
Las Vegas-Kingman	1	5.80	2	15	.75	.27	-20.5
Prescott	1	10.50	2	15	.75	.54	-32.6

Arena Summary

Daily Air Passengers	787
Number of Aircraft	21.22
Fleet Size	23
Return on Investment	28.5%
Aircraft Investment (000)	$2,599

Table 44. Analysis of Operational and Economic Characteristics--Cessna 402B

City Pair	Fleet Size	One-Way Fare, $	Total Daily Round Trips	Total Daily Air Passengers	Load Factor	Utilization Factor	Return On Investment, %
Phoenix-AJO	1	9.00	4	54	.75	.55	13.5%
Clifton	1	15.30	3	40	.74	.74	18.1
Douglas	1	15.50	2	27	.75	.61	1.9
Flagstaff	4	11.30	5	270	.75	.92	21.2
Ft. Huachuca	1	14.00	4	54	.75	.98	12.0
Globe	4	8.70	6	324	.75	.67	21.9
Grand Canyon	3	14.50	3	122	.75	.79	14.6
Holbrook	1	16.00	4	54	.75	.89	38.4
Kingman	1	15.00	3	40	.74	.77	13.5
Lk. Havasu City	1	16.80	4	54	.75	.90	52.1
Nogales	1	16.30	4	54	.75	.95	41.9
Page	1	17.50	2	27	.75	.74	-2.2
Parker	1	11.50	2	27	.75	.42	1.9
Prescott	1	11.00	6	81	.75	.81	57.7
Safford	1	20.50	4	54	.75	.89	89.1
San Manuel	1	9.50	5	67	.75	.75	14.6
Show-Low	2	17.40	5	134	.74	.98	84.3
Springerville	1	17.50	4	54	.75	1.00	44.5
Willcox	1	13.30	2	26	.72	.46	1.9
Winslow	1	13.50	3	40	.74	.61	16.6
Tucson-Ft. Huachuca	1	7.30	2	27	.75	.16	16.1
Douglas	1	8.30	2	27	.75	.28	4.4
Las Vegas-Kingman	1	5.00	2	20	.56	.28	-18.4
Prescott	1	8.00	2	26	.72	.56	-35.2

Arena Summary

Daily Air Passengers	1,703
Number of Aircraft	24.04
Fleet Size	26
Return On Investment	25.9%
Aircraft Investment(000)	$3,900

Table 45. Analysis of Operational and Economic Characteristics--Beech 99A

City Pair	Fleet Size	One-Way Fare, $	Total Daily Round Trips	Total Daily Air Passengers	Load Factor	Utilization Factor	Return On Investment, %
Phoenix-AJO	1	9.50	2	45	.75	.23	3.8%
Clifton	1	14.30	2	45	.75	.41	1.3
Douglas	1	12.50	2	45	.75	.50	-10.4
Flagstaff	4	14.50	2	180	.75	.30	10.9
Ft. Huachuca	1	15.00	2	45	.75	.40	4.1
Globe	4	13.50	2	179	.75	.19	17.2
Grand Canyon	1	22.30	4	90	.75	.87	44.6
Holbrook	1	17.00	2	45	.75	.37	12.8
Kingman	1	14.00	2	45	.75	.42	1.3
Lk. Havasu City	1	17.70	2	45	.75	.37	14.5
Nogales	1	17.30	2	45	.75	.39	12.0
Page	1	14.40	2	45	.75	.60	-13.6
Parker	1	9.00	2	45	.75	.35	-7.9
Prescott	1	10.50	4	90	.75	.45	13.0
Safford	1	17.00	3	67	.74	.55	18.0
San Manuel	1	12.30	2	45	.75	.25	8.0
Show-Low	1	19.70	6	134	.74	.97	69.9
Springerville	1	18.50	2	45	.75	.41	12.7
Willcox	1	10.00	2	44	.73	.38	7.1
Winslow	1	12.00	2	45	.75	.33	.8
Tucson-Ft. Huachuca	1	5.50	2	44	.73	.14	-4.0
Douglas	1	6.50	2	45	.75	.23	-5.6
Las Vegas-Kingman	1	10.00	2	7	.12	.23	-14.9
Prescott	1	6.00	2	44	.73	.46	-24.8

Arena Summary

Daily Air Passengers	1,509
Number Of Aircraft	11.27
Fleet Size	13
Return On Investment	3.4%
Aircraft Investment (000)	$5,915

Table 46. Analysis of Operational and Economic Characteristics--Swearingen Metro

City Pair	Fleet Size	One-Way Fare, $	Total Daily Round Trips	Total Daily Air Passengers	Load Factor	Utilization Factor	Return On Investment, %
Phoenix-AJO	1	8.60	2	57	.75	.19	3.2%
Clifton	1	13.00	2	57	.75	.35	2.8
Douglas	1	12.00	2	57	.75	.35	-6.9
Flagstaff	4	12.00	2	228	.75	.26	8.1
Ft. Huachuca	1	13.70	2	57	.75	.34	4.5
Globe	4	10.00	2	229	.75	.16	9.9
Grand Canyon	1	16.50	5	142	.75	.93	26.5
Holbrook	1	15.00	2	57	.75	.31	11.3
Kingman	1	13.00	2	57	.75	.36	2.2
Lk. Havasu City	1	16.00	2	57	.75	.32	13.1
Nogales	1	15.70	2	57	.75	.33	11.1
Page	1	13.50	2	57	.75	.52	-8.9
Parker	1	8.30	2	57	.75	.30	-5.6
Prescott	1	9.50	4	112	.74	.38	12.0
Safford	1	13.00	4	114	.75	.63	12.0
San Manuel	1	10.30	2	57	.75	.21	6.2
Show-Low	1	16.70	6	170	.75	.82	56.0
Springerville	1	16.80	2	56	.74	.35	11.8
Willcox	1	9.50	2	57	.75	.32	-4.8
Winslow	1	10.50	2	57	.75	.29	1.8
Tucson-Ft. Huachuca	1	5.20	2	56	.74	.11	.3
Douglas	1	6.30	2	54	.71	.20	-3.6
Las Vegas-Kingman	1	5.00	2	22	.29	.16	-12.0
Prescott	1	5.50	2	57	.75	.39	-19.6

Arena Summary

Daily Air Passengers	1,981
Number of Aircraft	9.84
Fleet Size	11
Return On Investment	-2.4%
Aircraft Investment (000)	$6,545

Table 47. Analysis of Operational and Economic Characteristics--Twin Otter

City Pair	Fleet Size	One-Way Fare, $	Total Daily Round Trips	Total Daily Air Passengers	Load Factor	Utilization Factor	Return On Investment, %
Phoenix-AJO	1	7.00	2	57	.75	.33	-3.9%
Clifton	1	10.30	2	57	.75	.59	-9.6
Douglas	1	9.50	2	56	.74	.72	-19.9
Flagstaff	4	10.00	2	225	.74	.44	-2.1
Ft. Huachuca	1	11.00	2	57	.75	.58	-7.5
Globe	4	8.00	2	223	.73	.27	3.6
Grand Canyon	1	18.30	3	86	.75	.95	17.7
Holbrook	1	11.50	2	57	.75	.53	-1.4
Kingman	1	10.50	2	56	.74	.61	19.8
Lk. Havasu City	1	12.70	2	57	.75	.54	.8
Nogales	1	12.70	2	57	.75	.57	-1.1
Page	1	10.70	2	57	.75	.87	-24.6
Parker	1	6.40	2	57	.75	.50	-14.8
Prescott	1	11.30	2	57	.75	.32	8.8
Safford	1	15.00	2	57	.75	.53	7.3
San Manuel	1	8.00	2	57	.75	.36	-2.0
Show-Low	1	18.00	4	114	.75	.93	40.4
Springerville	1	13.40	2	55	.72	.59	-1.5
Willcox	1	7.30	2	57	.75	.54	-15.0
Winslow	1	8.50	2	56	.74	.48	-8.5
Tucson -Ft. Huachuca	1	9.40	2	55	.72	.20	-4.6
Douglas	1	5.00	2	54	.71	.33	-9.8
Las Vegas-Kingman	1	5.00	2	15	.20	.33	-17.0
Prescott	1	5.00	2	57	.75	.67	-30.4

Arena Summary

Daily Air Passengers	1,737
Number of Aircraft	14.91
Fleet Size	16
Return On Investment	-16.2%
Aircraft Investment (000)	$8,800

1. Minimum frequency of service of two round trips per day.
2. A maximum 75% average seat load factor.
3. 3,000 hours maximum utilization.
4. Maximum fleet size of four aircraft on any city pair.
5. Maximize number of passengers carried in accordance with the lowest fare.

On some routes such as Phoenix-Globe or Phoenix-Flagstaff the use of the five-passenger Piper Aztec was unfeasible because of the large demand. The Beech 99A or Swearingen Metro could better this market although at a higher fare level.

The Twin Otter, because of the low speed, only performed well between Phoenix-Grand Canyon, Prescott, or Show-Low. The Beech 99A and Swearingen generally performed well radiating from Phoenix but poorly from Tucson or Las Vegas.

The Cessna 402B performed well out of all hubs except Las Vegas. However, for service between Phoenix-Flagstaff, Globe, and Grand Canyon the fleet size and number of daily round trips had to be significantly increased to meet the high demand.

A West Virginia aircraft evaluation summary similar to that of Arizona is shown in Table 48 for the Cessna 402B and Piper Aztec. The larger aircraft were not included as their economic feasibility was well below that of the above two aircraft. This analysis showed that even with minimum fares such service by any aircraft is nonviable.

An analysis of the operational and economic characteristics of these aircraft is illustrated in Tables 49 and 50. This analysis shows that there is not one city pair that generates enough demand to support scheduled air service with a minimum frequency of two round trips per day.

Table 48. Aircraft Evaluation Summary--
West Virginia Arena

Aircraft	Daily Air Passengers	Number of Aircraft	Fleet Size	Return on Investment, %	Aircraft Investment (000)
Cessna 402B	78	2. 48	3	-106. 1	$600
Piper Aztec	67	2. 39	3	-107. 3	452

Table 49. Analysis of Operational and Economic Characteristics--Piper Aztec Turbo E

City Pair	Fleet Size	One-Way Fare, $	Total Daily Round Trips	Total Daily Air Passengers	Load Factor	Utilization Factor	Return On Investment, %
Charleston-Beckley	1	5.00	2	4.9	.25	.15	-16.4
Bluefield	1	5.00	2	5.5	.28	.23	-25.2
Clarksburg	1	5.00	2	7.2	.36	.29	-29.9
Huntington	1	5.00	2	2.3	.12	.16	-21.5
Morgantown	1	8.00	2	15.0	.75	.37	-22.8
Parkersburg	1	5.00	2	5.8	.30	.21	-22.5
Huntington-Beckley	1	5.00	2	5.1	.26	.26	-28.6
Parkersburg	1	5.00	2	7.5	.38	.27	-27.9
Parkersburg-Clarksburg	1	5.00	2	3.4	.17	.20	-23.2
Morgantown	1	5.00	2	9.6	.48	.25	-24.2

Arena Summary

Daily Air Passengers	67
Number of Aircraft	2.39
Fleet Size	3
Return On Investment	-107.3%

Table 50. Analysis of Operational and Economic Characteristics--Cessna 402B

City Pair	Fleet Size	One-Way Fare, $	Total Daily Round Trips	Total Daily Air Passengers	Load Factor	Utilization Factor	Return On Investment, %
Charleston-Beckley	1	5.00	2	5.4	.15	.24	-25.0
Bluefield	1	5.00	2	5.4	.15	.24	-25.0
Clarksburg	1	5.00	2	7.1	.20	.30	-30.1
Huntington	1	5.00	2	2.2	.061	.17	-19.4
Morgantown	1	5.50	2	27.0	.75	.39	-23.5
Parkersburg	1	5.00	2	5.6	.16	.21	-22.0
Huntington-Beckley	1	5.00	2	5.0	.14	.27	-28.1
Parkersburg	1	5.00	2	7.4	.21	.28	-27.9
Parkersburg-Clarksburg	1	5.00	2	3.3	.092	.21	-22.5
Morgantown	1	5.00	2	9.4	.26	.26	-24.5

Arena Summary

Daily Air Passengers	78
Number of Aircraft	2.48
Fleet Size	3
Return On Investment	-106.1%

B. IDENTIFICATION OF VIABLE ROUTES, AIRCRAFT AND OPERATING CONCEPTS

1. IDENTIFICATION OF PROMISING ROUTES

Table 5 tabulates the nonstop routes for the 34 city pairs analyzed. The first 20 city pairs are Type A nonstop routes with Phoenix, Arizona being the hub city which is both a major trading center and a major air hub. The 20 rural communities vary in population from below 2,000 to about 25,000 persons and range in travel distance between city pairs ranges from sixty to two hundred and fifty miles. All but two of the city pairs can be provided with viable air service with a minimum of two nonstop round trip flights per day. The Type A city pairs in general represent the highest possible travel demand (all modes) and the greatest possible trip distance involved in local rural travel.

The next ten (21-30) city pairs are Type B nonstop routes with the hub cities being either a major trading center or a major air hub. Three hub cities were analyzed: Tucson, Arizona (major air hub), Las Vegas, Nevada (major air hub) and Charleston, West Virginia (major trading center). All of the ten city pairs proved nonviable for nonstop air service for each of the five aircraft analyzed. However, the two smaller aircraft did not lose money on three city pairs. In general, these Type B city pairs represent lower rural travel demands and shorter trip distances than the Type A city pairs.

The last four (31-34) city pairs are Type C. Here the hub city is neither a major air hub nor a major trading center. The total travel demand is lower and trip distances shorter than with the Type B city pairs. The four Type C city pairs all proved uneconomical for air service with a minimum of two nonstop round trips per day.

Figure 17 is a plot of total two-way daily travel demand (all modes) against air trip distance in miles for each of the 34 city pairs. The

routes are noted as Type A, B, or C and the viable routes are shown as shaded circles and the unviable routes as open circles. This plot shows a reasonable correlation of viability of air service as a function of both trip distance and total travel demand between communities. If we proceed horizontally across the figure at a daily demand of 300 person trips we see that air service becomes viable at approximately 100 miles. Similarly, if we proceed vertically up the figure at 150 miles we require a minimum total travel demand of approximately 200 daily person trips for viable air service with a minimum of two daily round trips. The nonstop air service will be economically marginal at demands and distances just below the viable levels, and with still lower demand levels and shorter distances it will prove totally nonviable. In these marginal cases the local modal split will determine the viability of nonstop air service. Routes other than nonstop should also be considered for these marginal city pairs.

The example of "Scheduled Stop-on-Demand" in Section IV-A-1 shows promise of converting some of these marginal nonstop routes to part of a viable low-density air system. Other routes such as linear multi-stop routes between two Type A hub cities should also be studied but are not covered in this report.

2. VIABLE AIRCRAFT

The results of this study identify unmistakably the aircraft types that offer the best chance for viable low density air service. From inspection of Table 5 it is seen that the two smallest capacity aircraft (5-9 seats) are predominant in the viable routes examined in detail. Further substantiating this trend is the fact that the two largest capacity aircraft (19 seats) share in the smallest percentage of viable routes. These results are summarized according to aircraft capacity as shown in Table 51.

Table 51. Identification of Viable Aircraft

Aircraft	Capacity	Number of Viable Nonstop Routes
Piper Aztec Turbo E	5	16
Cessna 402B	9	16
Beech 99A	15	11
Swearingen Metro	19	8
Twin Otter	19	3

This summary assumes that a fair return on investment of 10.5% is achieved. At smaller ROIs, the larger aircraft can participate in a greater number of viable air routes, but so can the smaller capacity aircraft. The conclusion emerges from these results that one of the most important factors in achieving profitable low-density air transportation is the sizing of the aircraft to the routes.

C. IDENTIFICATION OF PROMISING RESEARCH AND DEVELOPMENT AREAS

A review of the Nonstop Route Viability Summary (Table 5) shows that small aircraft in the five- to nine-passenger capacity are capable of offering viable nonstop air service to the greatest number of rural communities. To state this another way, aircraft capacity must be carefully matched to the route air passenger demand so as to achieve load factor allowing a profitable operation. Figure 36 shows the breakeven fare required versus nonstop air distance as a function of load factor for the five-passenger Piper Aztec, the nine-passenger Cessna 402B, and the

15-passenger Beech 99A. Even though the larger aircraft are more economical to operate, the demand is not available in most rural regions to fill the seats of the larger aircraft.

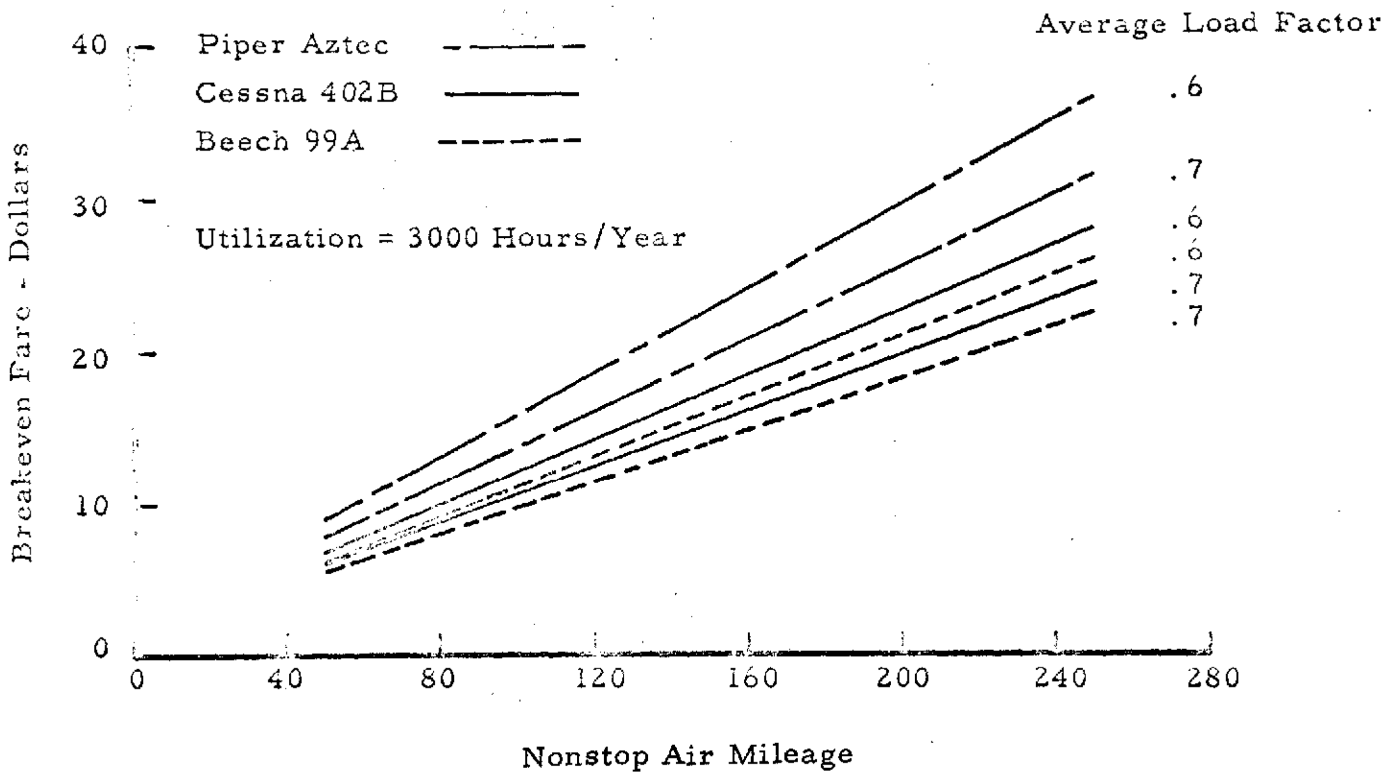


Figure 36. Breakeven Fare - Distance Analysis

To understand the sensitivity studies a detailed cost per trip analysis was made for each of the five aircraft on many of the routes. Table 52 shows the sensitivity study cost analysis for Phoenix-Willcox for the Cessna 402B. This is a route where none of the five

Table 52. Sensitivity Cost Analysis, Phoenix-Willcox-
149 Statute Miles

Cessna 402B, Capacity=9 Pass., Fleet Size=1, Round Trips=2, Fare=$19

	Nominal	ΔV=50 mph	ΔU= -500 hr	ΔDOC= -10%	ΔIOC= -10%
Operations Param./Trip					
Daily Passengers	14.9	17.25	14.9	14.9	14.9
Load Factor	.460	.486	.460	.460	.460
Avg. Cruise, mph	163	213	163	163	163
Block Speed, mph	158	205	158	158	158
Max. Cruise, mph	224	274	224	224	224
Utilization, hr/yr	3000	3000	2500	3000	3000
Flyaway Cost, $	150,000	150,000	150,000	150,000	150,000
Cost/One-Way Trip, $ DOCs					
Flight Crew	14.27	11.00	14.28	15.25	14.27
Direct Maint.	14.09	10.85	14.09	11.90	14.09
Fuel & Oil	8.84	6.81	8.84	5.50	8.84
Depreciation	4.70	3.62	5.64	5.02	4.70
Hull Insurance	.94	.72	1.12	.73	.94
DOC/Trip	42.84	33.01	43.97	38.37	42.84
IOCs					
Reserv. & Sales	7.78	8.05	7.78	7.78	6.99
Gen. & Admin.	7.08	7.34	7.08	7.08	6.36
A/C & Traffic Serv.	6.98	7.23	6.98	6.98	6.27
Pass. Serv. & Ins.	3.58	3.71	3.58	3.58	3.22
Deprec. Grnd. Equip.	.34	.34	.34	.34	.30
IOC/Trip	25.75	26.68	25.75	25.75	23.14
Total Cost/Trip	68.59	59.69	69.72	64.12	65.98
Annual Profit (Loss) Above ROI	(26,600)	30,200	(28,450)	(19,750)	(22,500)

aircraft were viable. On this route a 50 mph increase in cruising speed for the Cessna 402B changed the route from a loss of $26,600 per year to an excess profit (above 10.5% return on investment) of $2,200 per year.

Examination of each of the sensitivity results allows ranking the studies to be ranked in the order of their cost reduction value as follows:

1. Increasing the average cruise speed 50 mph provided the largest favorable impact. This had the effect of reducing the direct operating costs 23% and the total operating costs 13%, since block speed is a major parameter in all DOC elements. This higher speed resulted in increased passenger revenue and a small increase in indirect operating cost.
2. Decreasing overall direct operating costs 10% was not nearly as effective as increasing the average cruise speed 50 mph since it only reduced the overall operating costs by approximately 6.5%.
3. Decreasing indirect operating costs by 10% only reduced total operating costs by approximately 4%.
4. Decreasing annual utilization by 500 hours increased the hourly cost of hull insurance and depreciation by 20%. However, this cost is only 13% of the DOC so the overall direct operating costs only increased by approximately 2.6%.

Some of the potential areas where technical improvements would have attractive economic payoffs are shown in Table 53 which lists for the nominal case the cost elements per trip in percent of total cost per trip.

The cost of the flight crew is the largest single cost item for this nine-passenger aircraft with only one pilot. For larger aircraft, 10 to 19 passengers, two pilots are required, making the flight crew costs an even larger percentage of the total cost. Efforts should be expended to simplify the aircraft cockpit and controls so that larger aircraft can be certified for single pilot operation.

The direct maintenance is the second highest cost item. A comparison of the depreciation costs with the maintenance costs shows

Table 53. Trip Cost Allocation by Percent

	Percent of Total Cost/Trip
Flight Crew - DOC	20.8
Direct Maintenance - DOC	20.5
Fuel and Oil - DOC	12.9
Reservations and Sales - IOC	11.3
General and Administrative - IOC	10.3
Aircraft and Traffic Service - IOC	10.2
Depreciation - DOC	6.8
Passenger Service and Liability Insurance - IOC	5.2
Hull Insurance - DOC	1.4
Depreciation Ground Equipment - IOC	0.6
Total Cost/Trip	100.0
DOC/Trip	62.3
IOC/Trip	37.7

that it would probably be worth while to develop an aircraft that was more reliable even if the aircraft and engines cost twice as much initially if the result was a 50% reduction in the direct maintenance cost.

The fuel and oil costs appear unrealistically high when compared to the costs of the larger airlines. It was found this cost was not due to aircraft or engine inefficiencies causing a higher fuel consumption but was caused by a fuel cost per gallon for the commuter carrier exactly twice the cost of local and trunk carriers. It is believed at least a 40% reduction in fuel costs could result by bulk buying by groups of commuter carriers.

The reservation and sales expense could be reduced for rural carriers by having all ticketing and sales at the hub airport. The passenger would board the aircraft at the rural community and pay at the ticket gate (counter) upon departure from the aircraft at the hub terminal. Reservations could be made by long distance phone to this hub city.

The general and administrative expense runs approximately 10%. This cost could be reduced by broadening the operations base by also utilizing the commuter aircraft for charter operations, mail and air cargo. This also increases the revenue and aircraft utilization.

The aircraft traffic service expense also runs about 10% of the total operating cost. This item can be reduced for a rural carrier by eliminating all ground personnel at all airports except the hub terminal. With only two or three daily five minute stops at each of the rural communities utilization of full time employees becomes very inefficient. The aircraft should be designed so that no ground personnel are required at all but at the hub airport. This would include space in the aircraft for all baggage which would be carried on by the passengers and passenger loading ramps if required which are automatic and part of the aircraft.

Passenger service and liability insurance is the last appreciable cost item running slightly over 5% of the total cost. Passenger service

currently is a minimum on rural carriers; however, the liability insurance for commuter carriers is based on the available seat miles rather than revenue passenger miles like the local and trunk carriers. This cost can be reduced one of two ways, either by sizing the capacity of the aircraft to the route, thus allowing operation at a higher load factor, or by the commuter carriers buying insurance as a group and thus achieving lower rates.

As the aircraft block speed increases the IOC items become an even larger percent of the total operating costs so the need for aircraft changes such as carry-on baggage racks, and built-in loading ramps become more significant. In addition, as the aircraft speed increases we must not forget the rural air carrier is still confronted with short fields and runways so the desired aircraft configuration is a small capacity, high speed, short takeoff and landing, low maintenance aircraft.

D. DETAILED RESULTS

1. ARIZONA

Twenty-four Arizona city pairs were analyzed in detail for each of the five candidate aircraft based on nonstop operation. Five of these routes were chosen as being representative of the 24 and these have been discussed previously. The complete set of results, however, are contained in this section (Figures 37 through 55) to enable detailed comparison with one another.

2. WEST VIRGINIA

Ten West Virginia city pairs were analyzed in detail for two of the five candidate aircraft based on nonstop operation. It was evident early in the study that the larger capacity aircraft, i. e., the Beech 99A, Twin Otter, and Swearingen Metro, were economically unsuited to the West Virginia arena and so were not included. Two of the West Virginia routes

were chosen as being representative of the ten and these have been discussed previously. The complete set of results, however, is contained in this section (Figures 56 through 63) to enable detailed comparison.

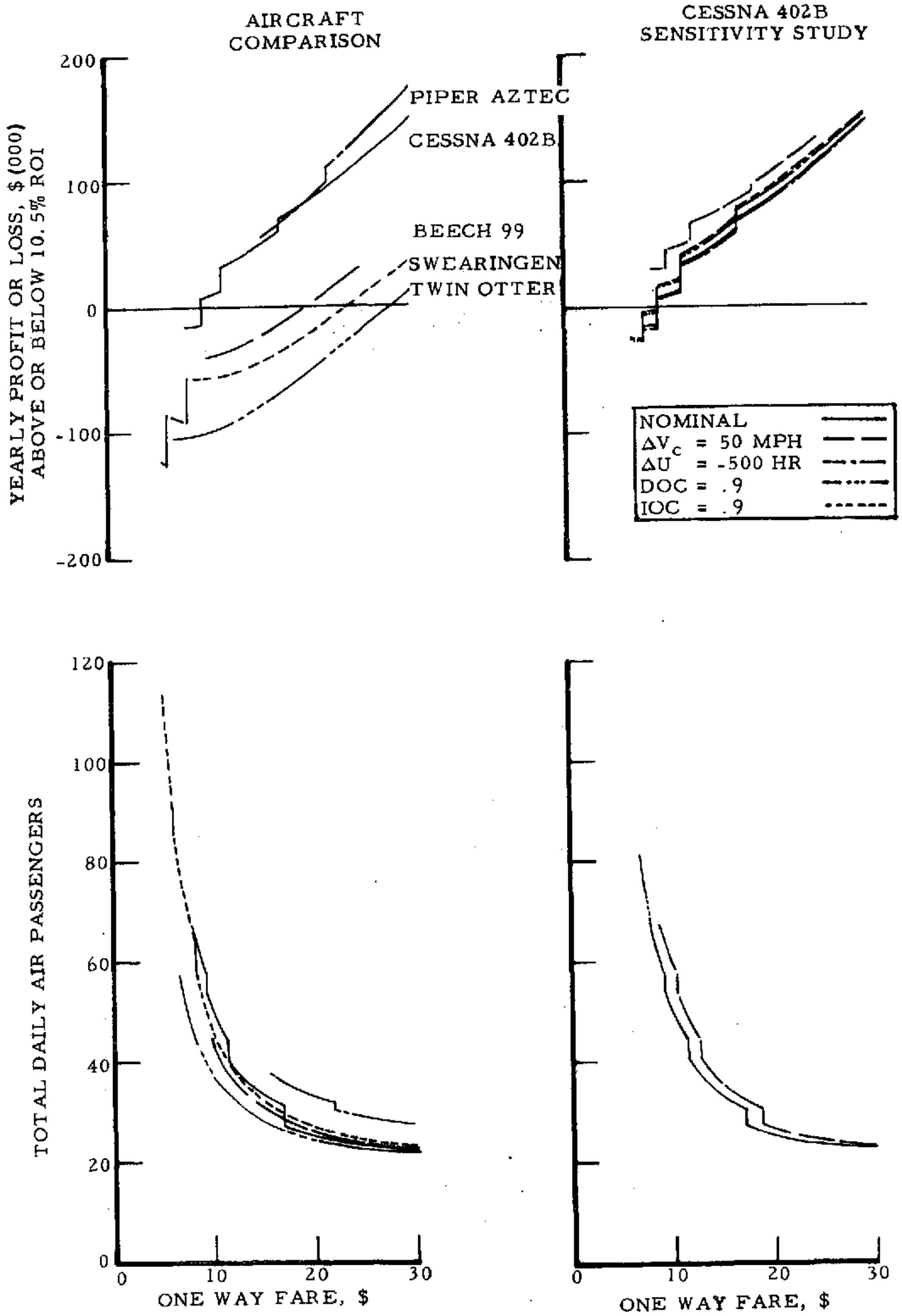


Figure 37. Phoenix-Ajo

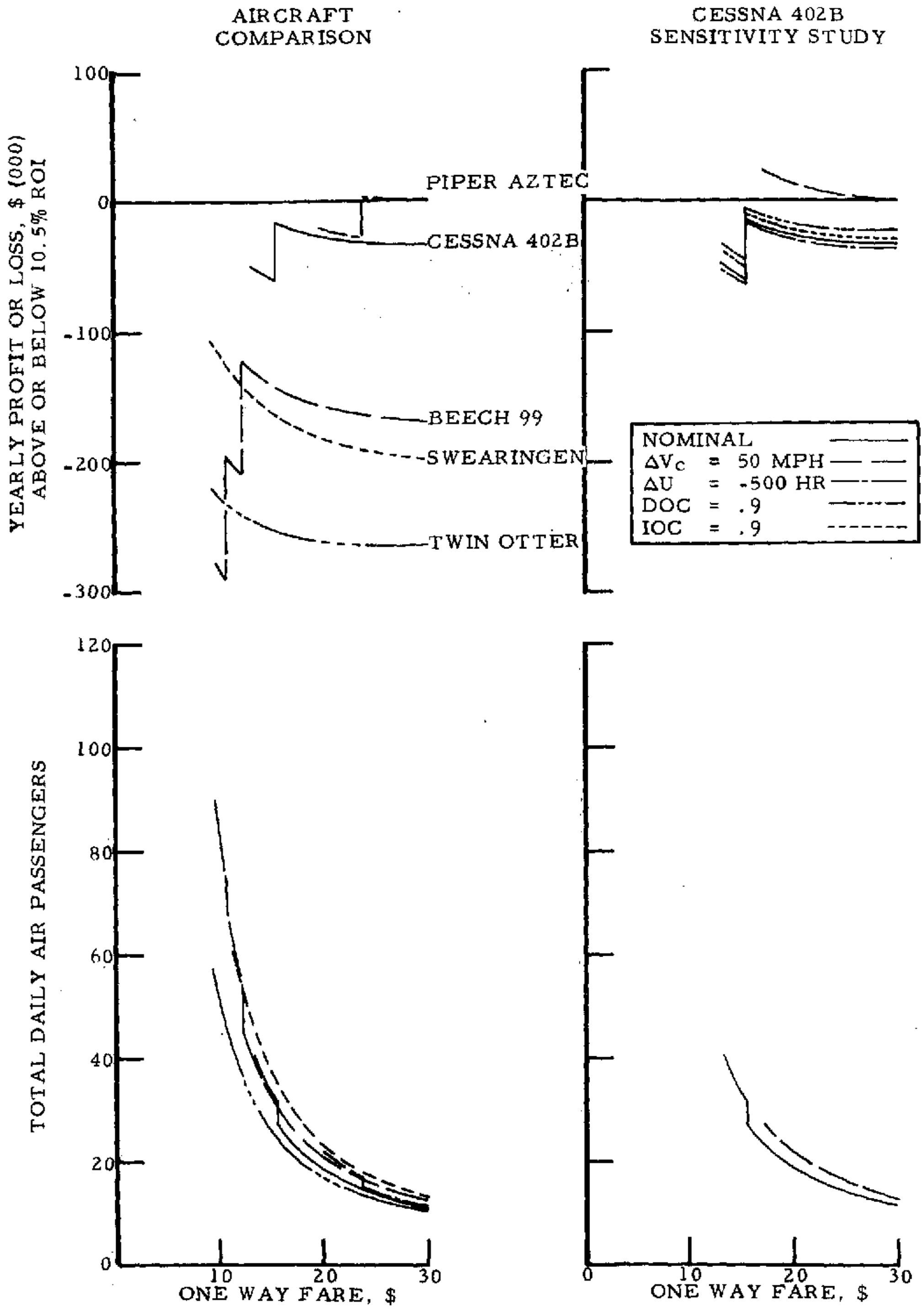


Figure 38. Phoenix-Douglas

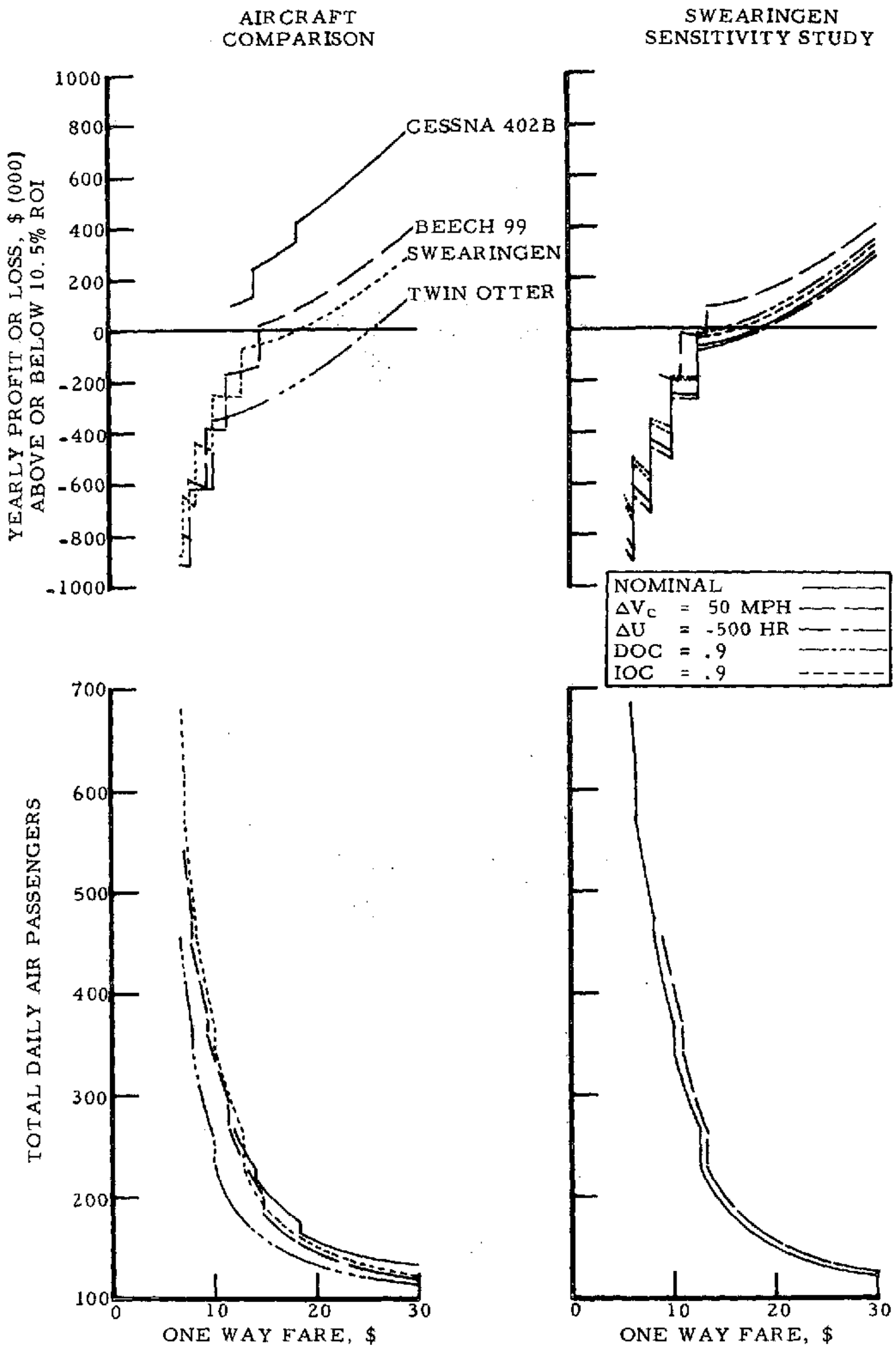


Figure 39. Phoenix-Flagstaff

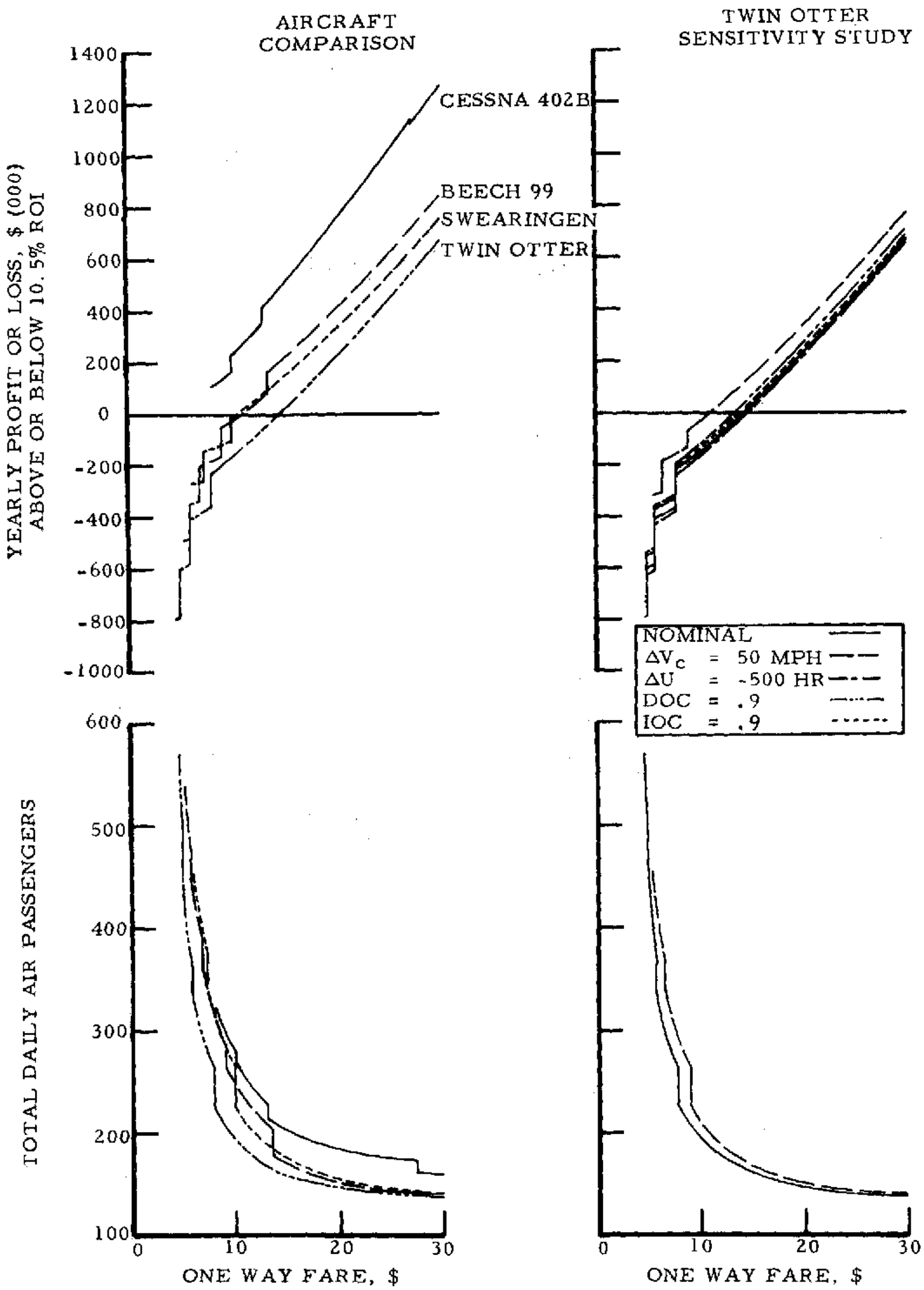


Figure 40. Phoenix-Globe

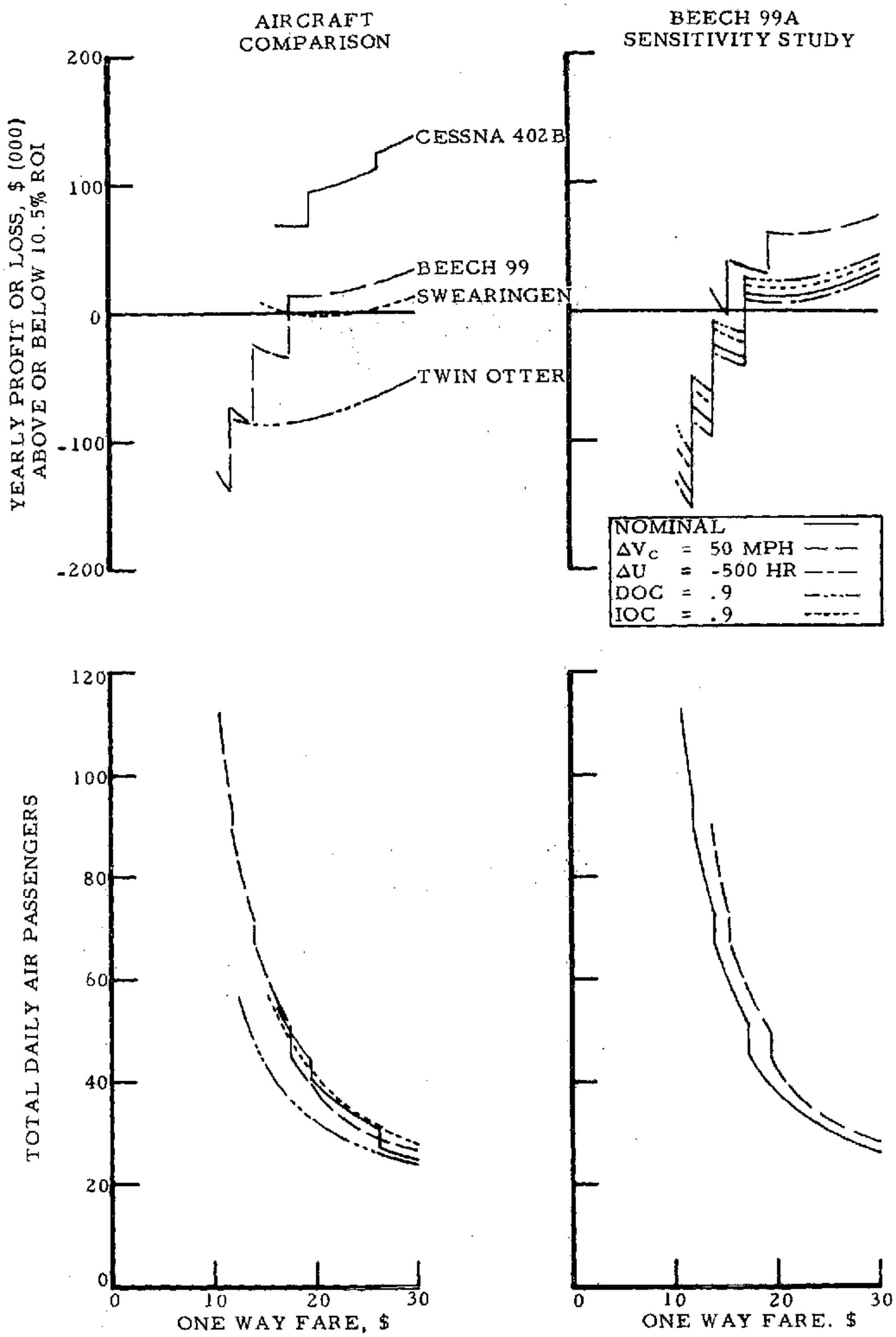


Figure 41. Phoenix-Holbrook

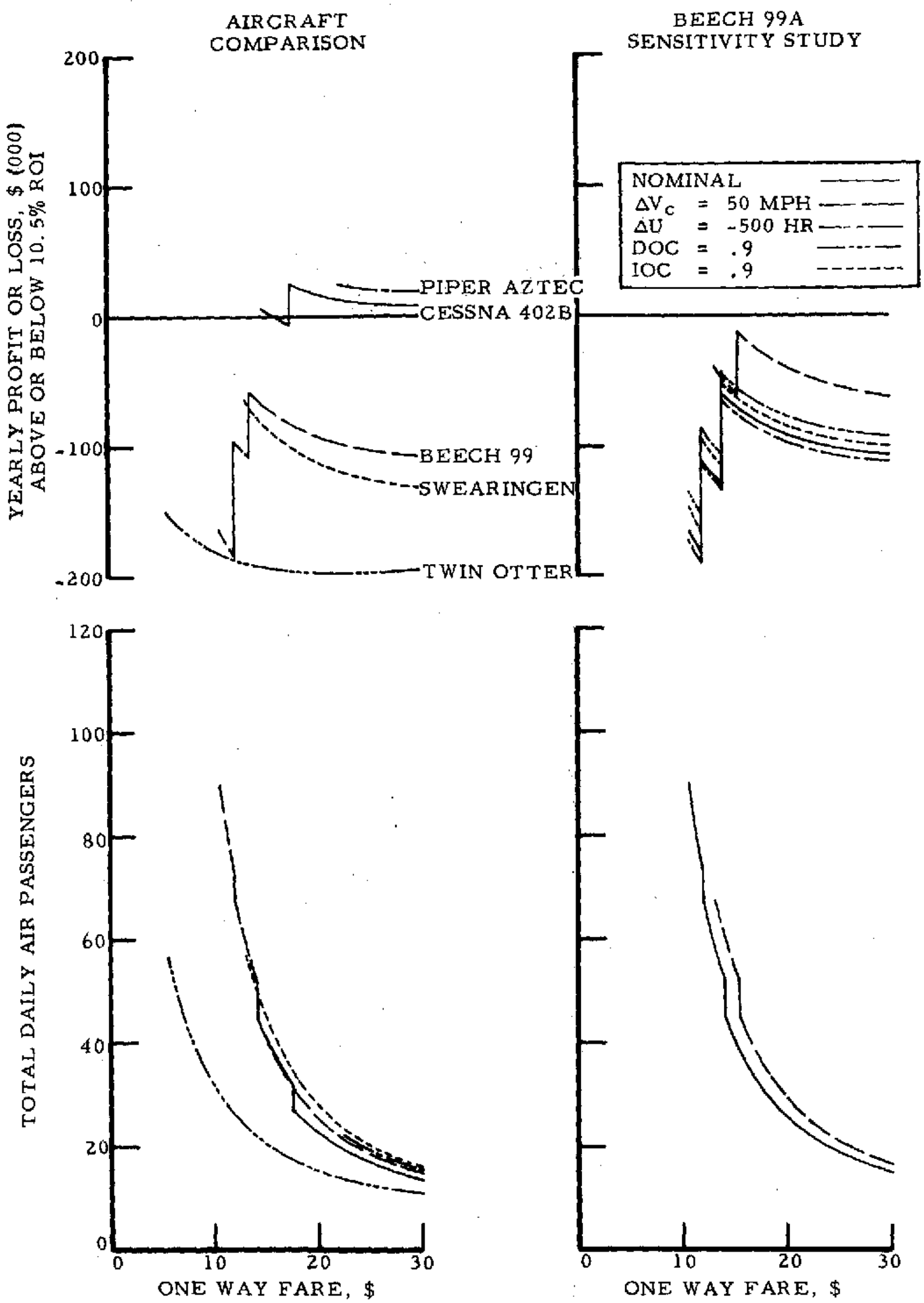


Figure 42. Phoenix-Kingman

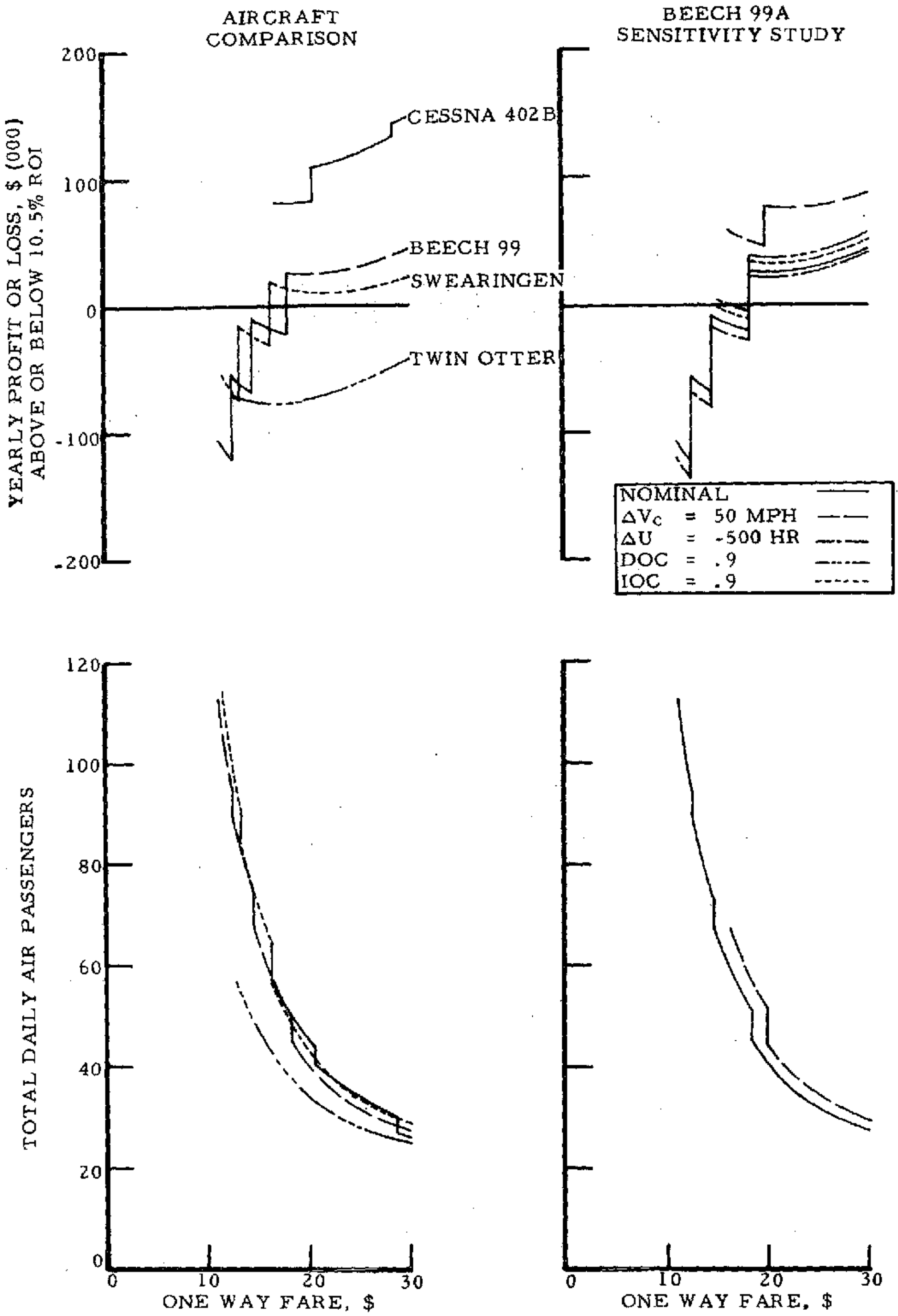


Figure 43. Phoenix-Lake Havasu City

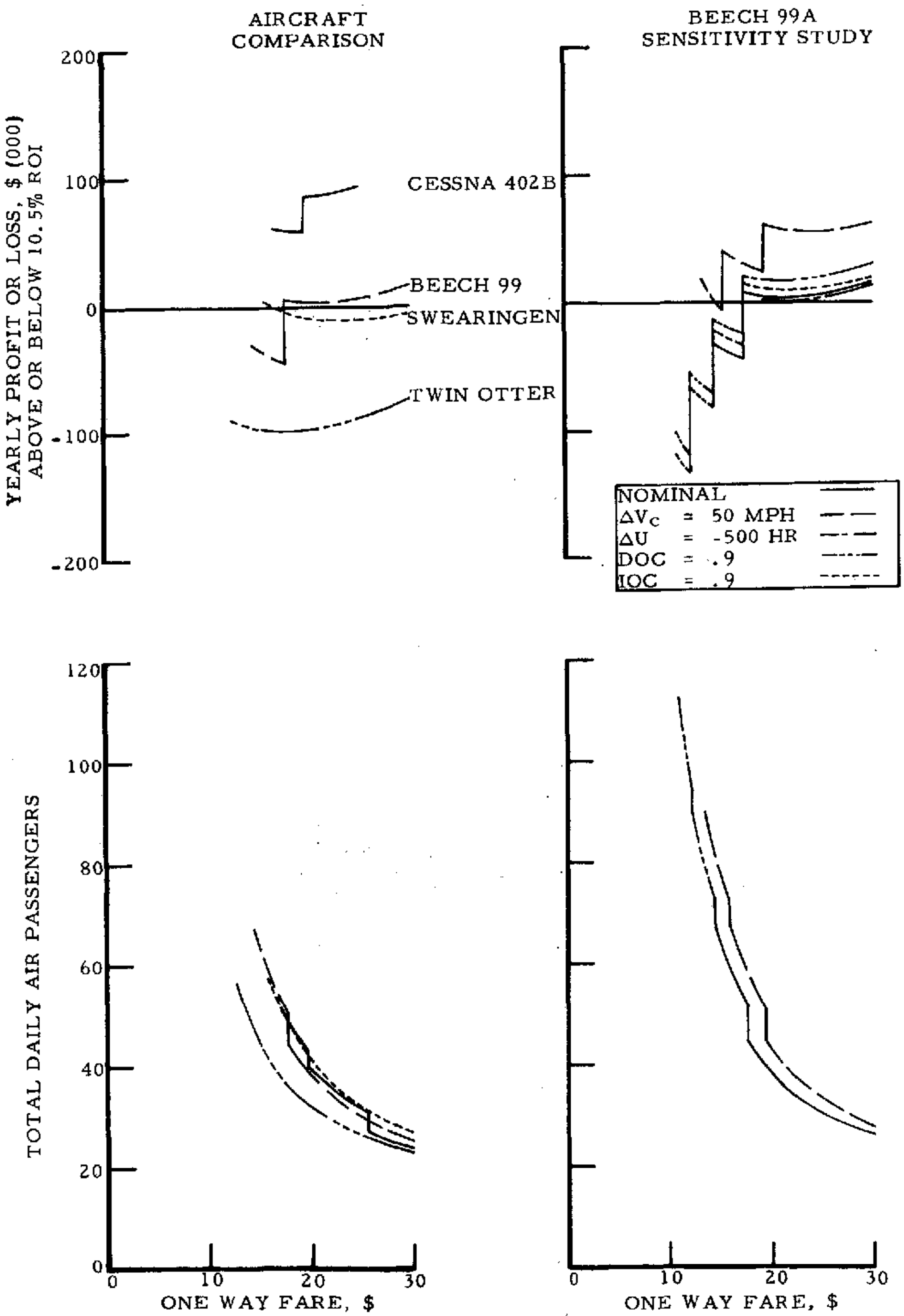


Figure 44. Phoenix-Nogales

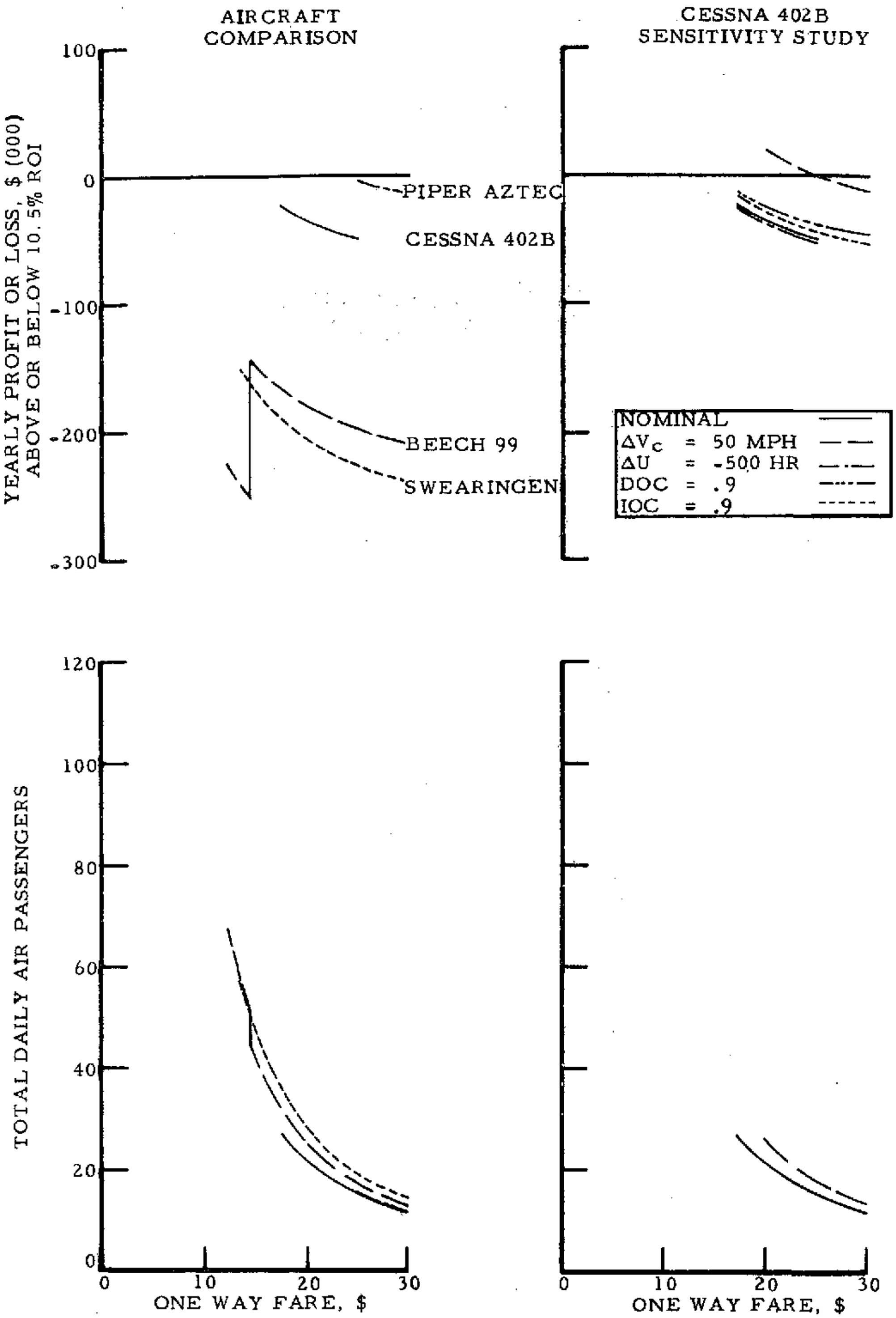


Figure 45. Phoenix-Page

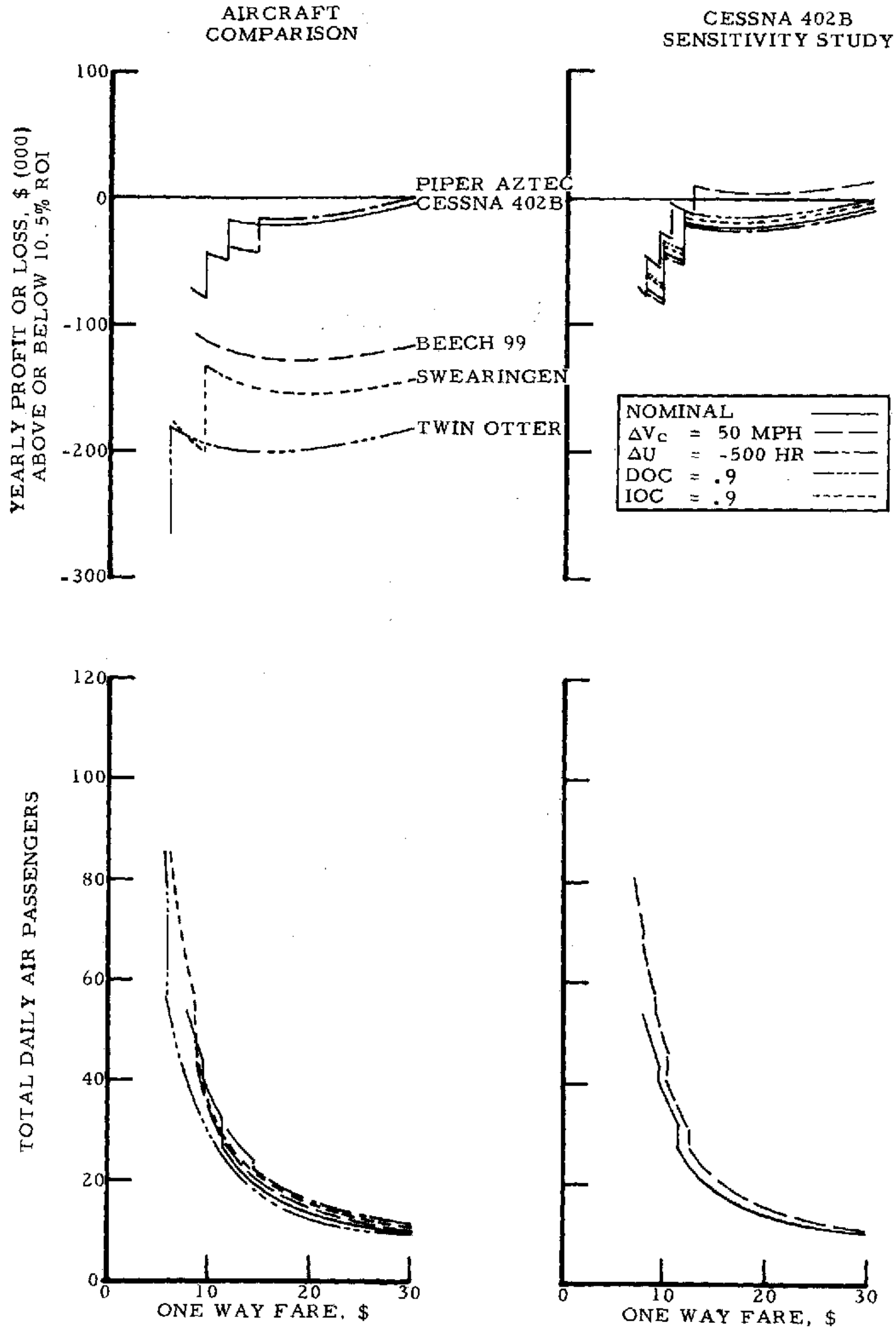


Figure 46. Phoenix-Parker

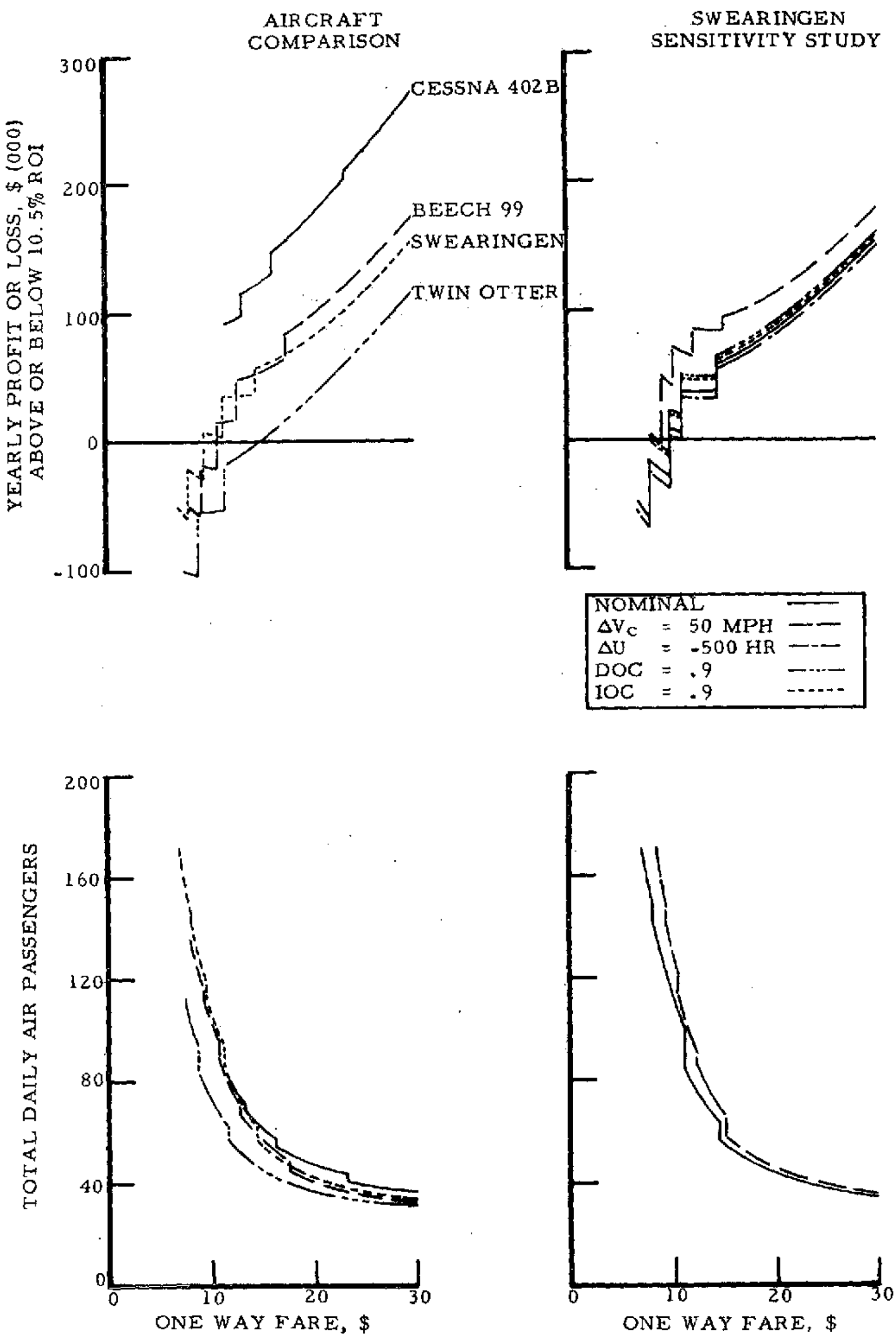


Figure 47. Phoenix-Prescott

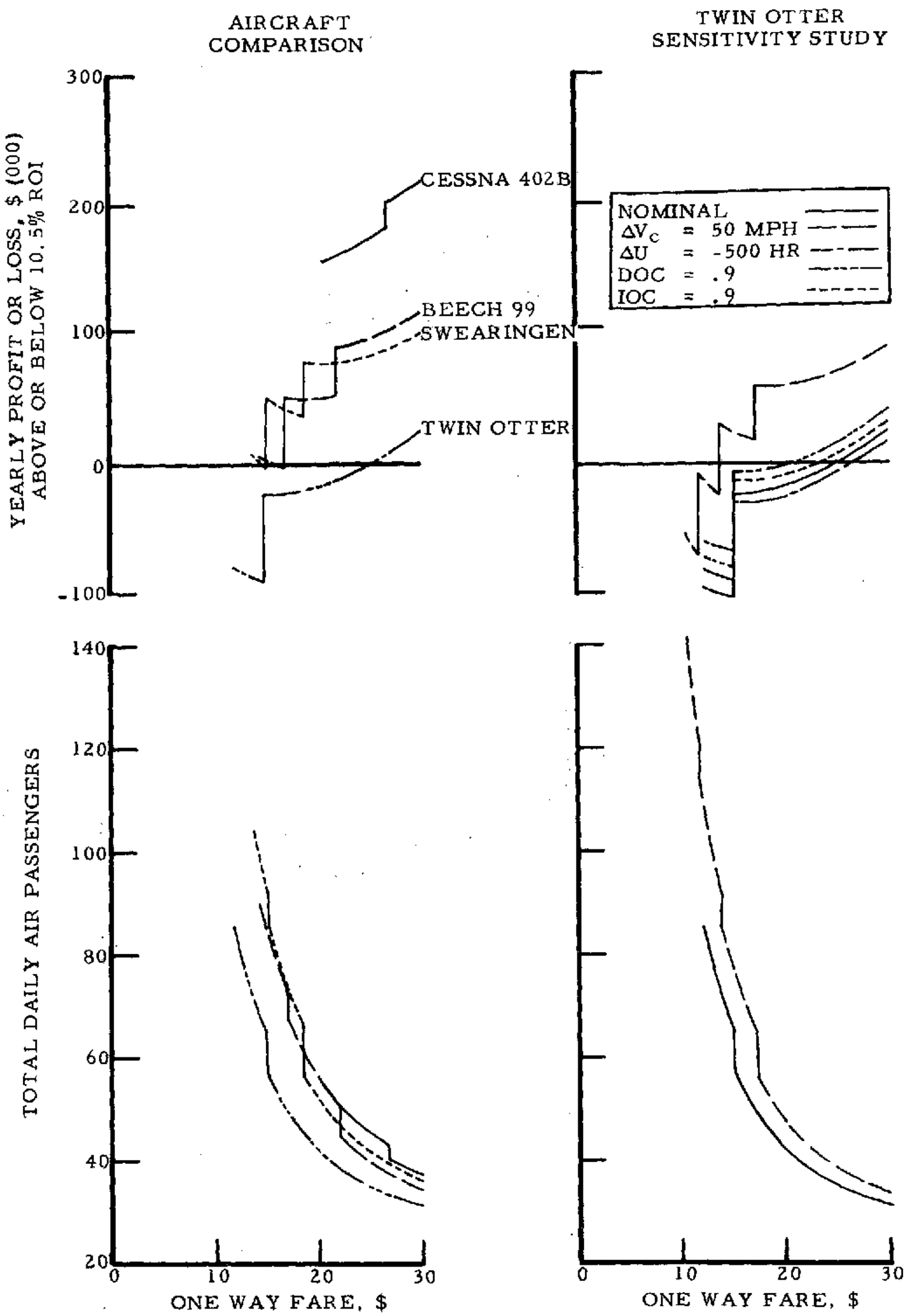


Figure 48. Phoenix-Safford

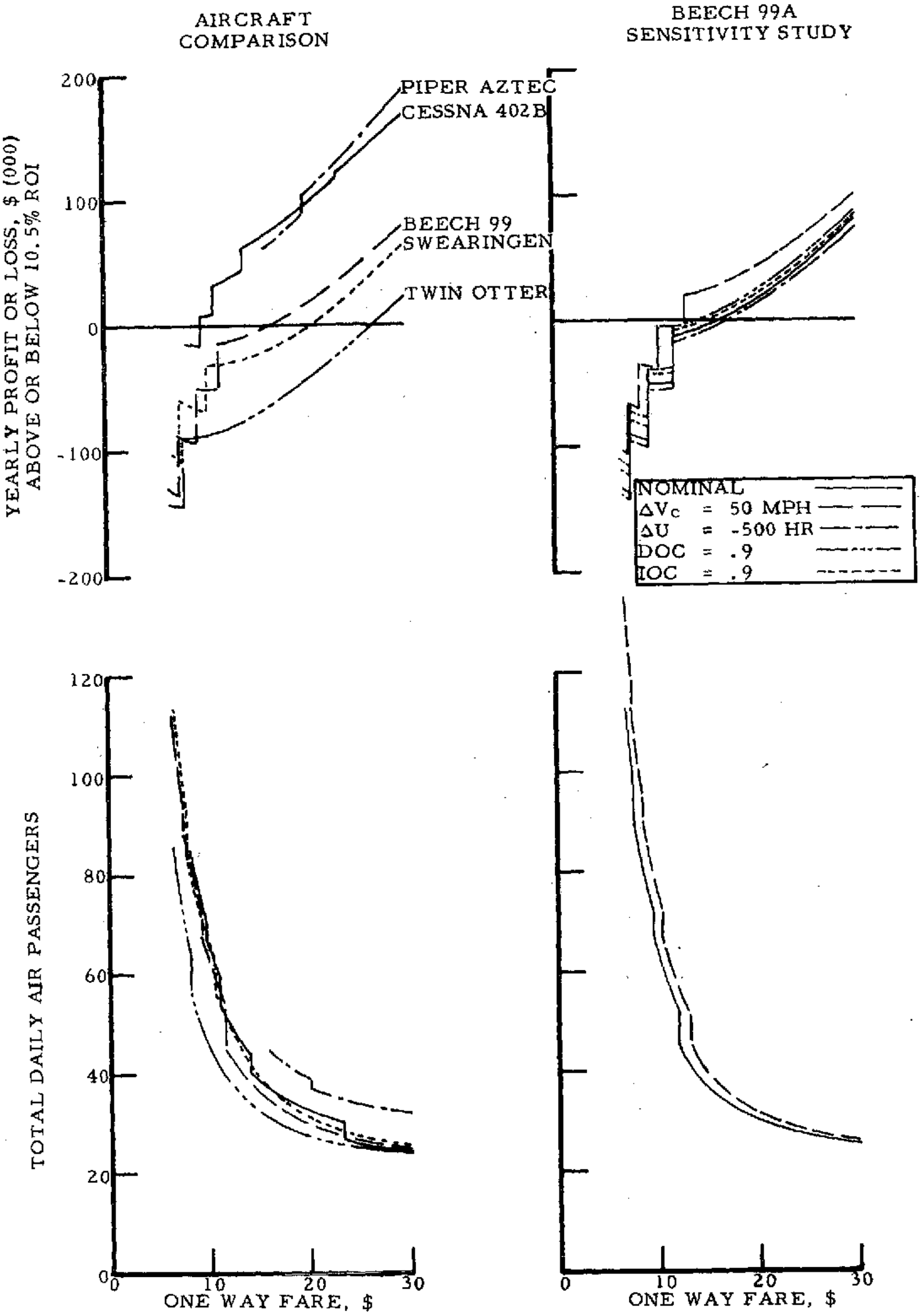


Figure 49. Phoenix-San Manuel

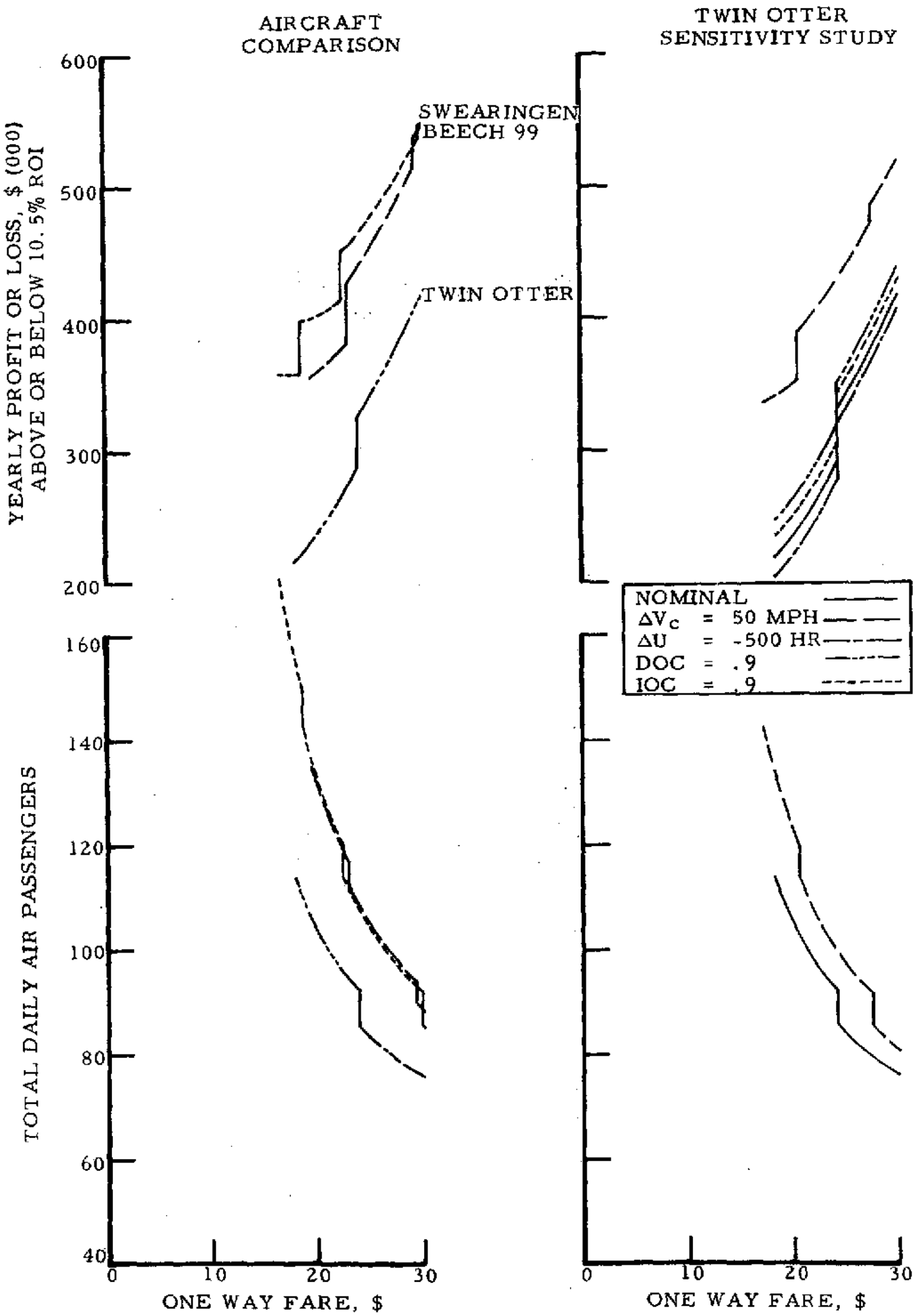


Figure 50. Phoenix-Show Low

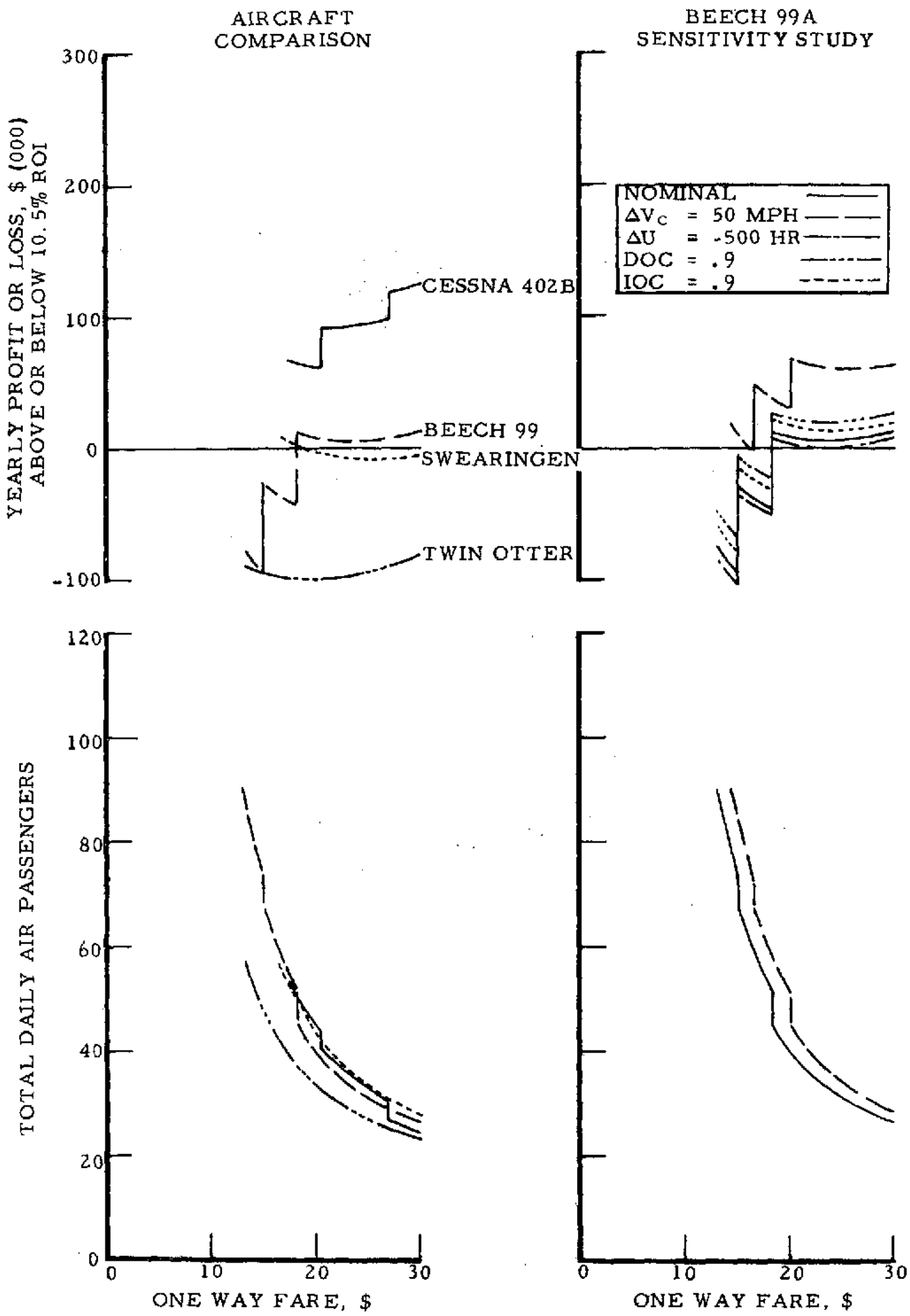


Figure 51. Phoenix-Springerville

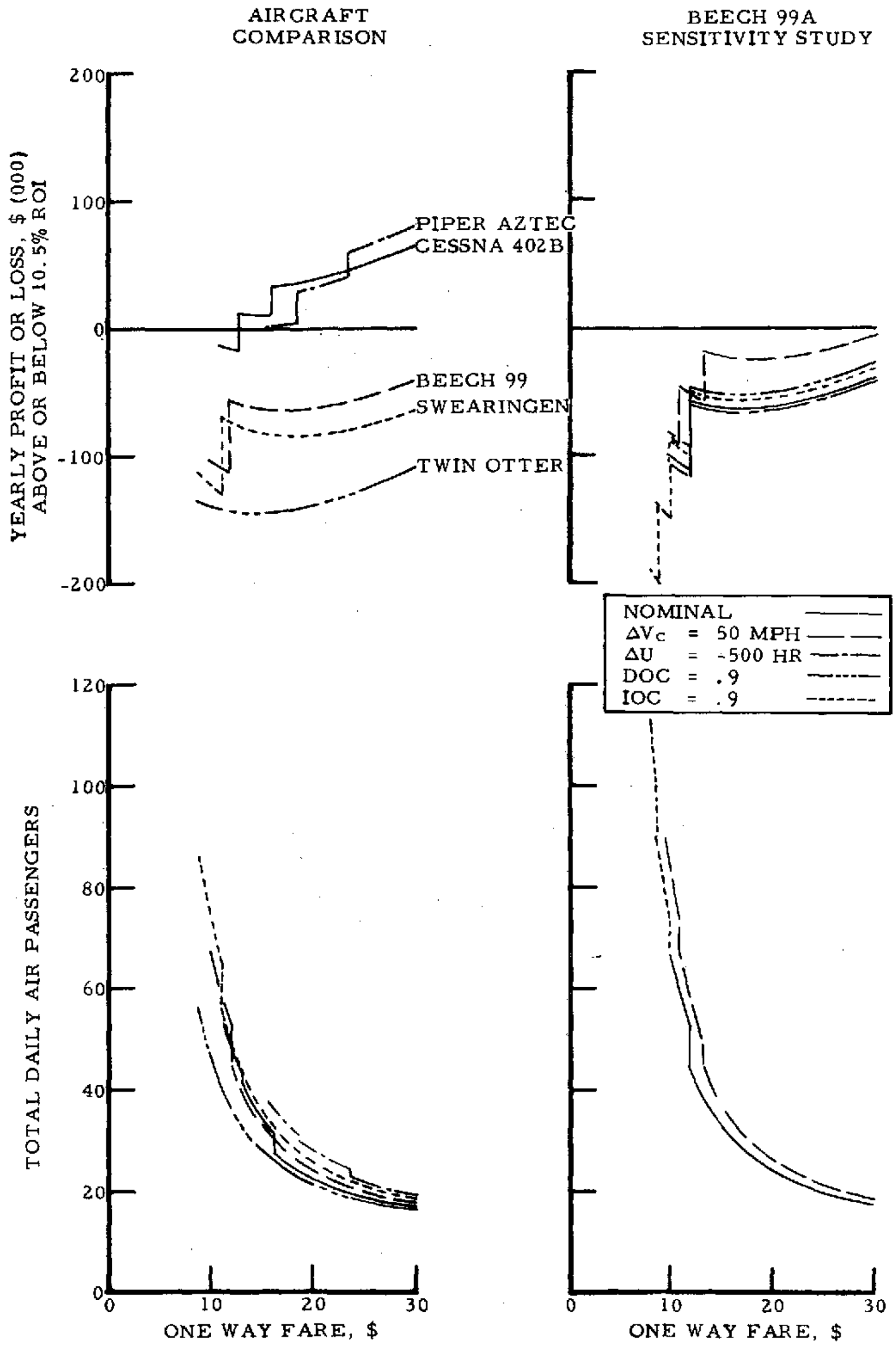


Figure 52. Phoenix-Winslow

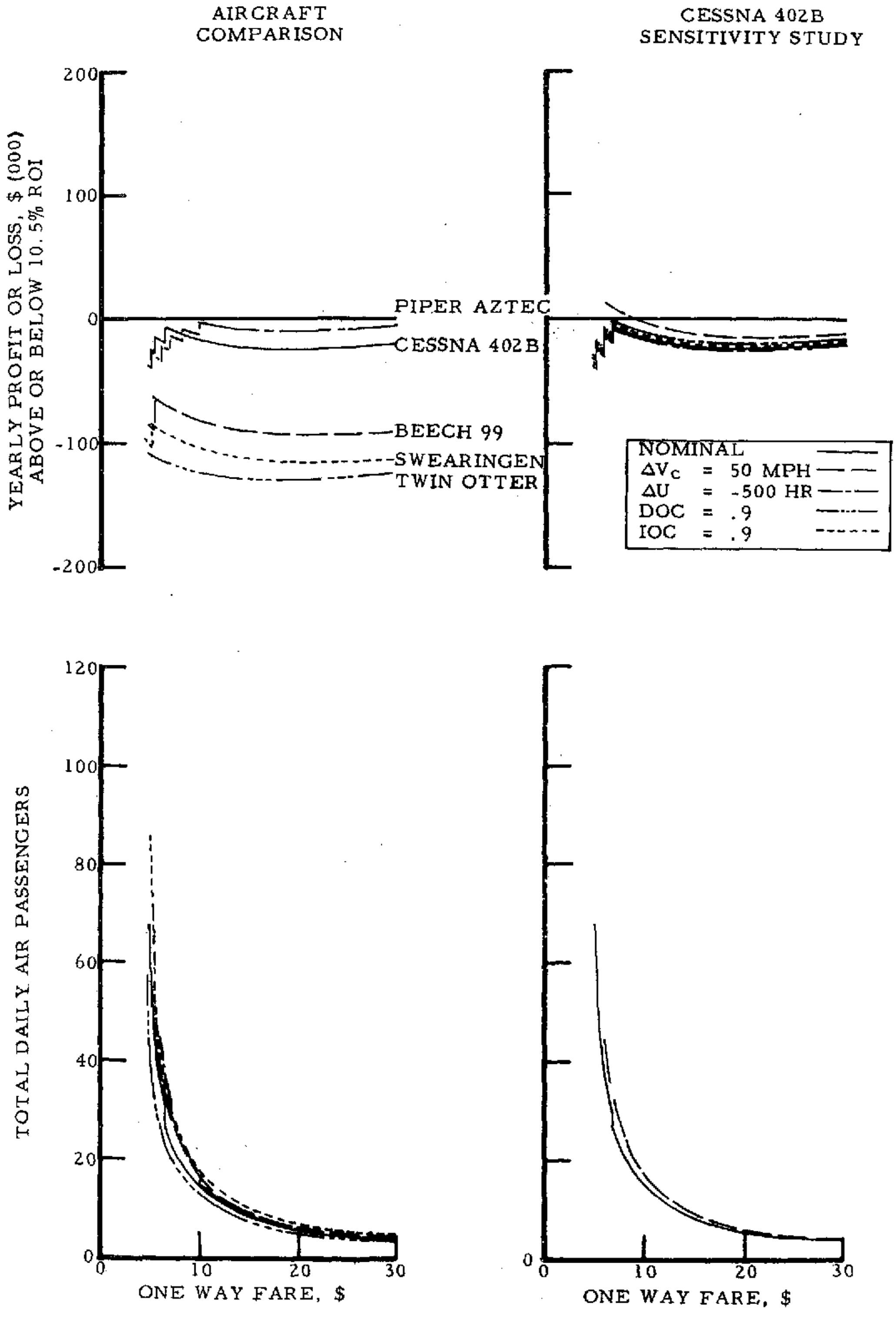


Figure 53. Tucson-Ft. Huachuca

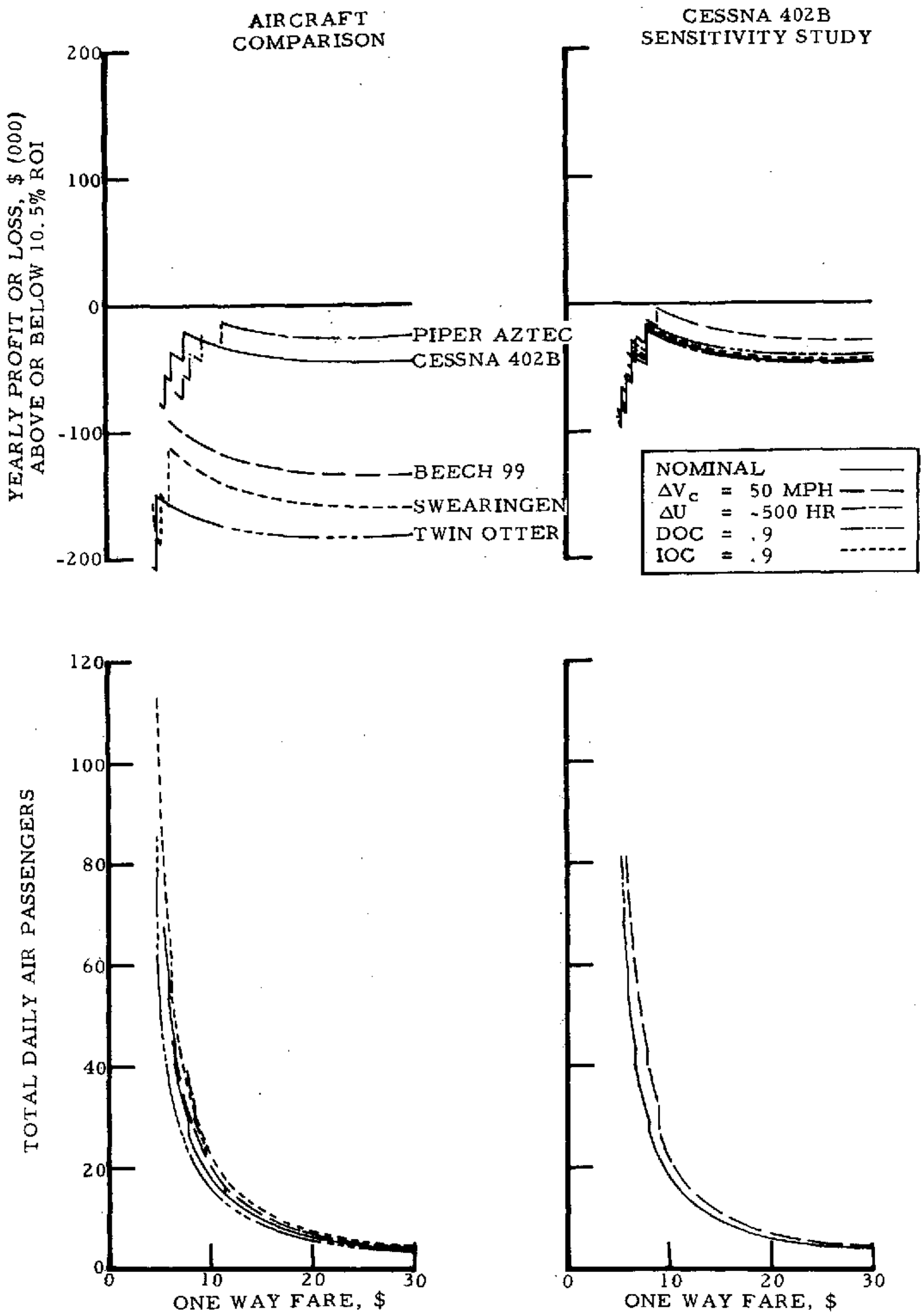


Figure 54. Tucson-Douglas

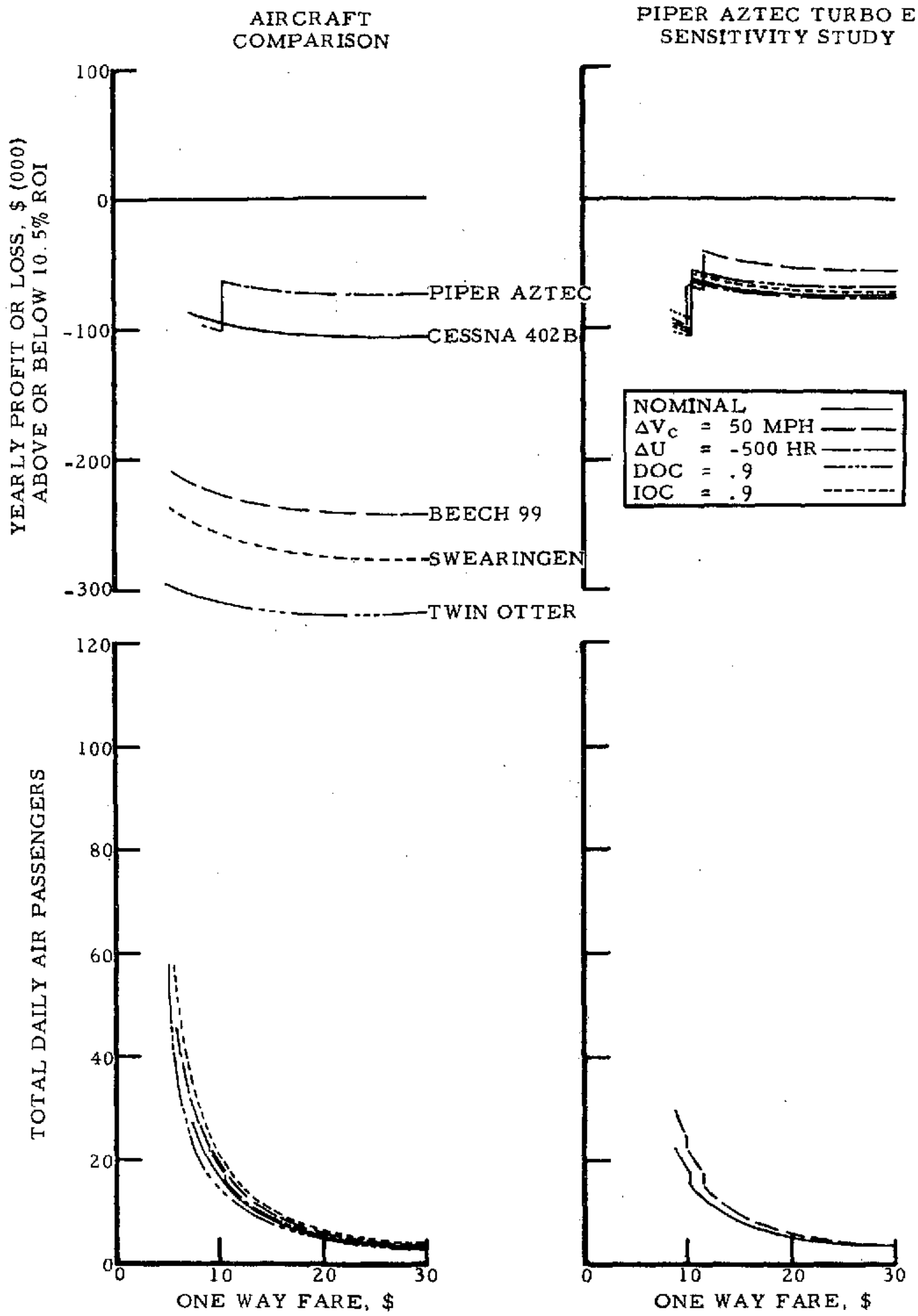


Figure 55. Las Vegas-Prescott

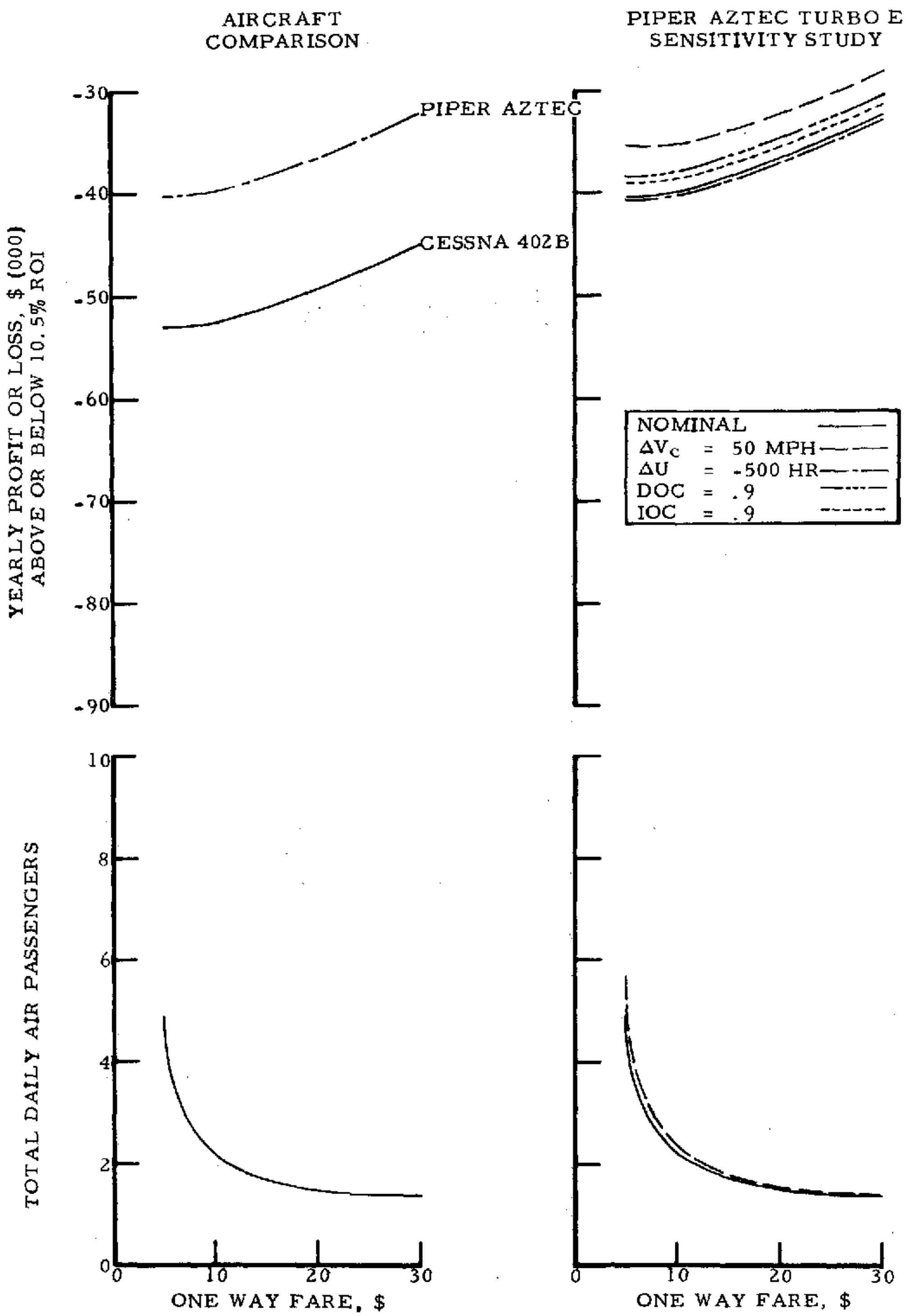


Figure 56. Charleston-Beckley

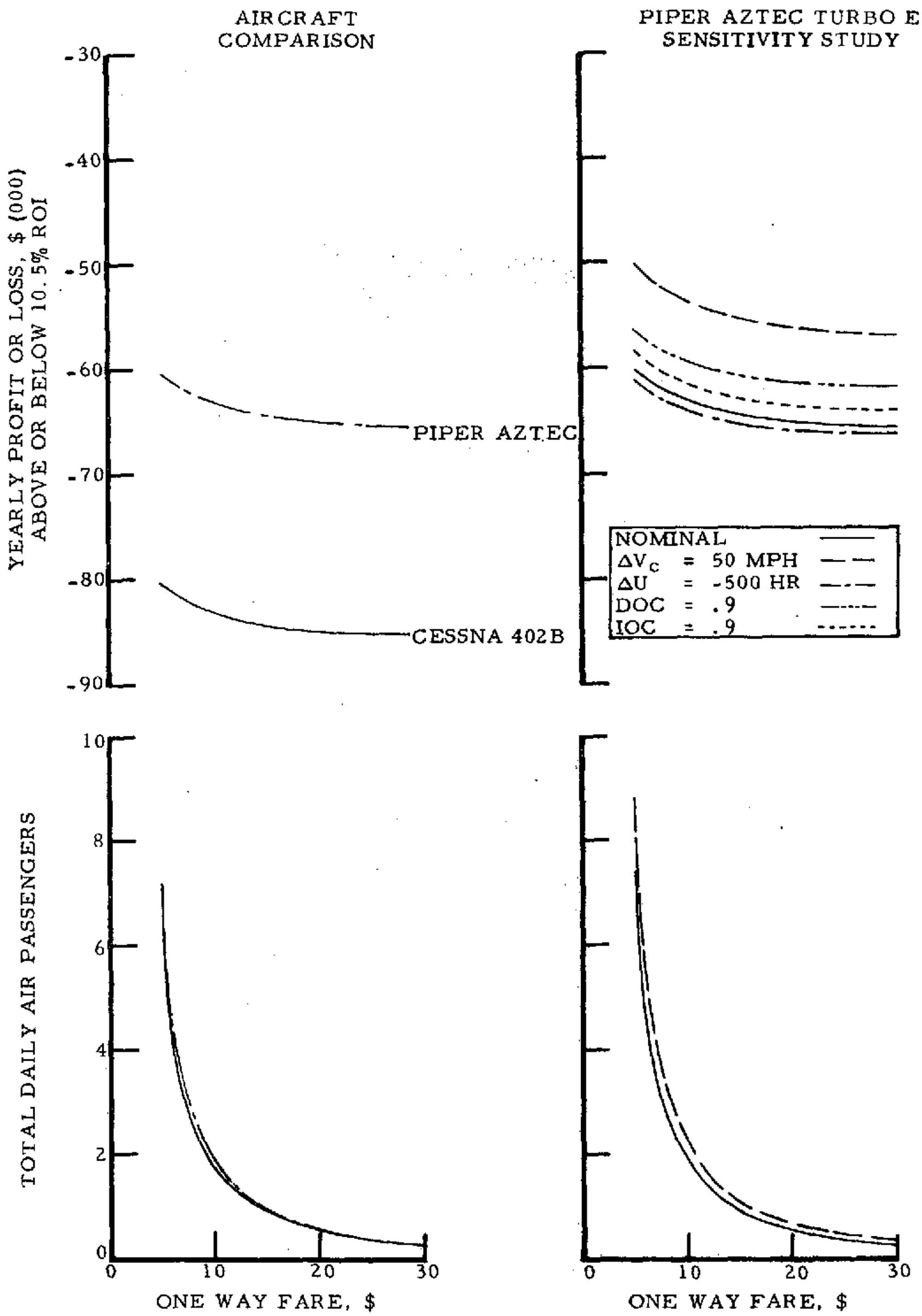


Figure 57. Charleston-Clarksburg

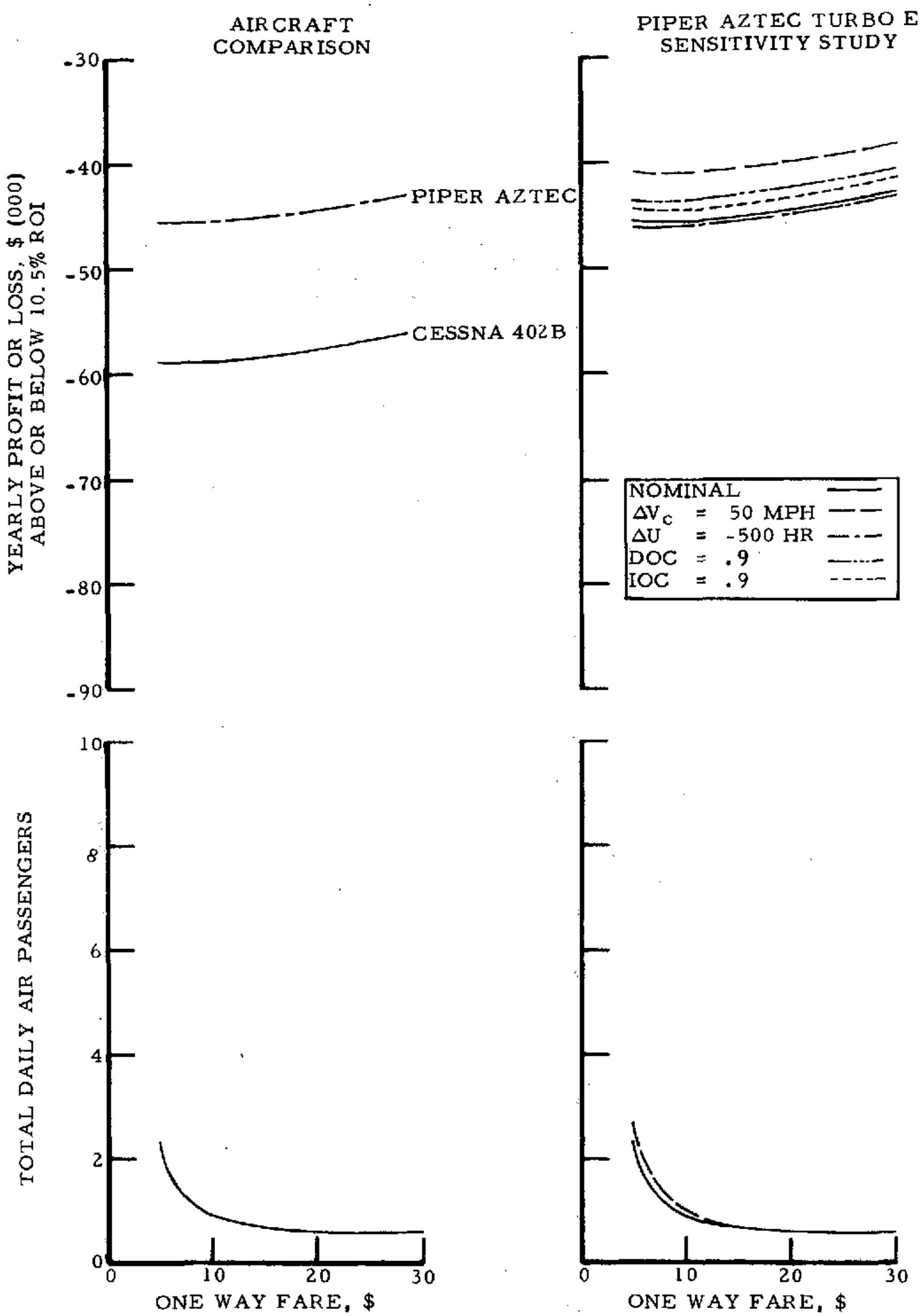


Figure 58. Charleston-Huntington

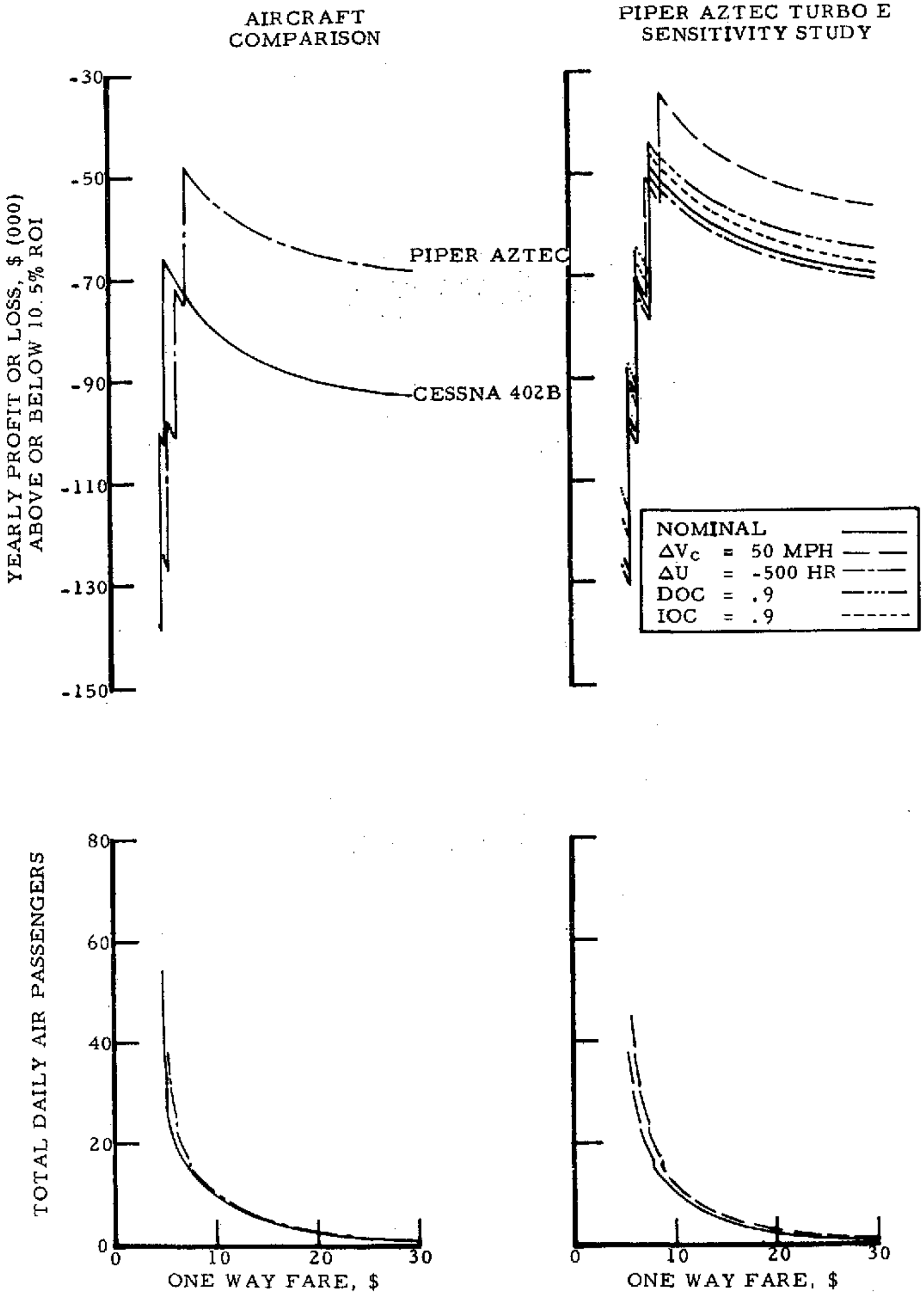


Figure 59. Charleston-Morgantown

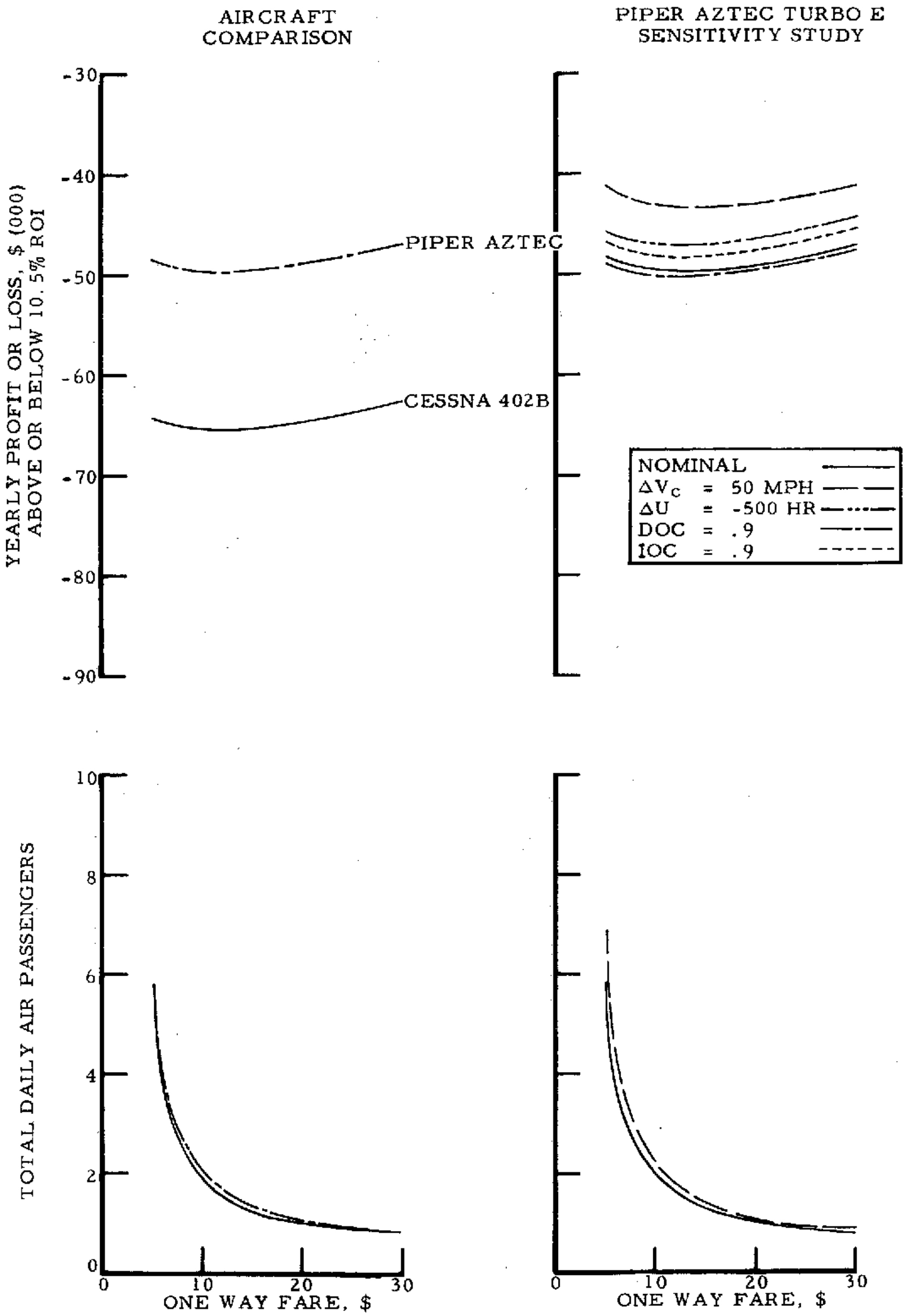


Figure 60. Charleston-Parkersburg

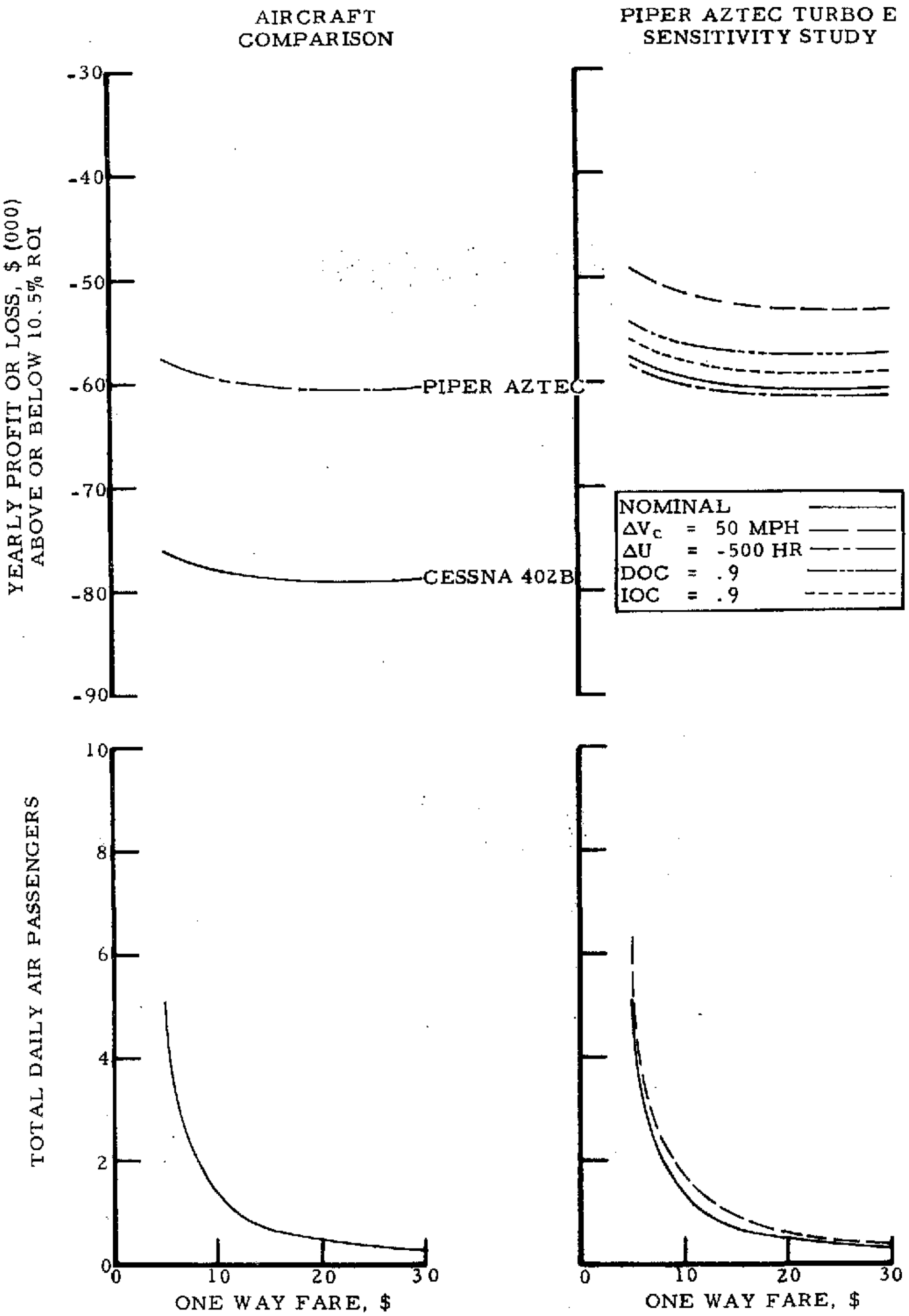


Figure 61. Huntington-Beckley

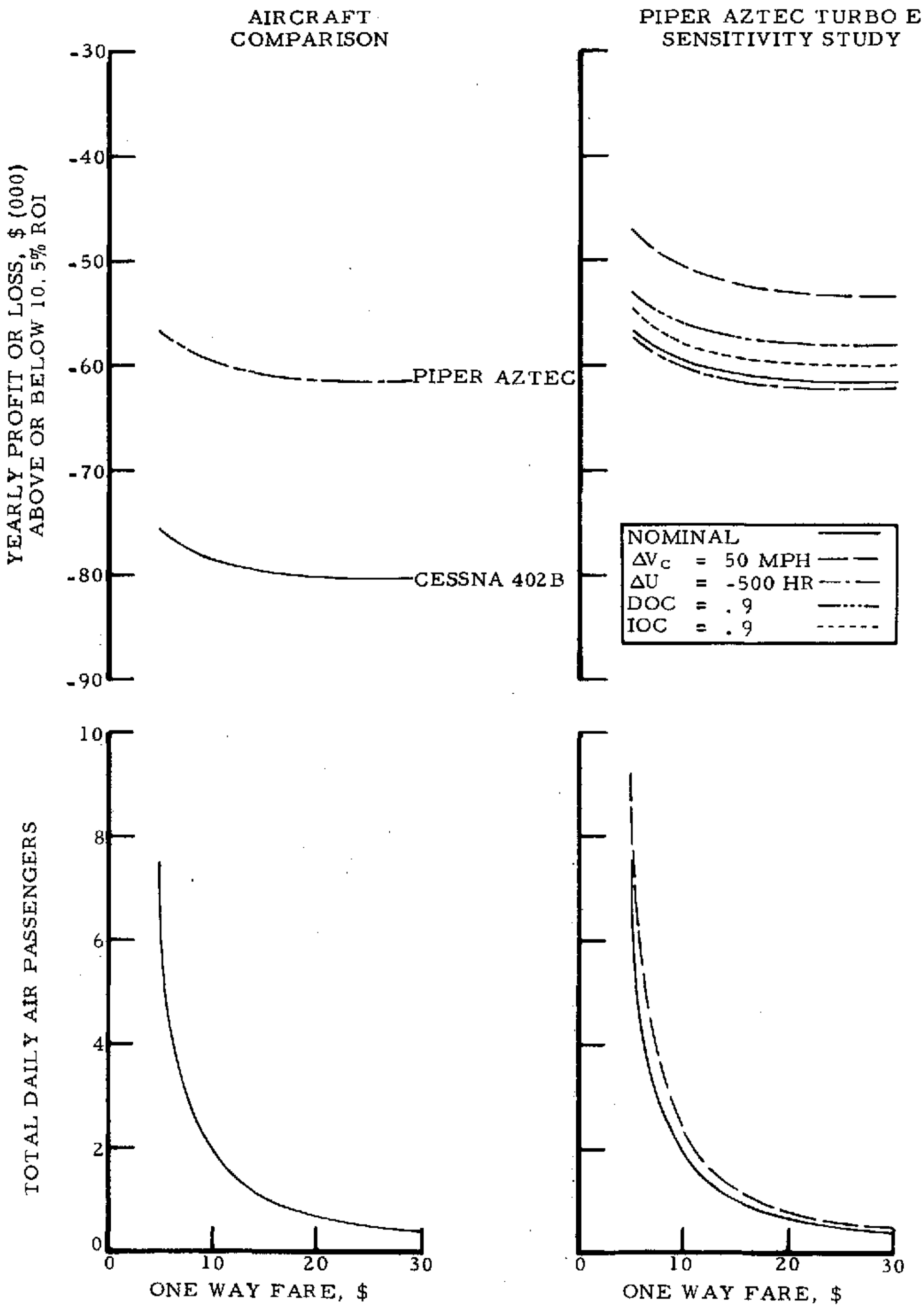


Figure 62. Huntington-Parkersburg

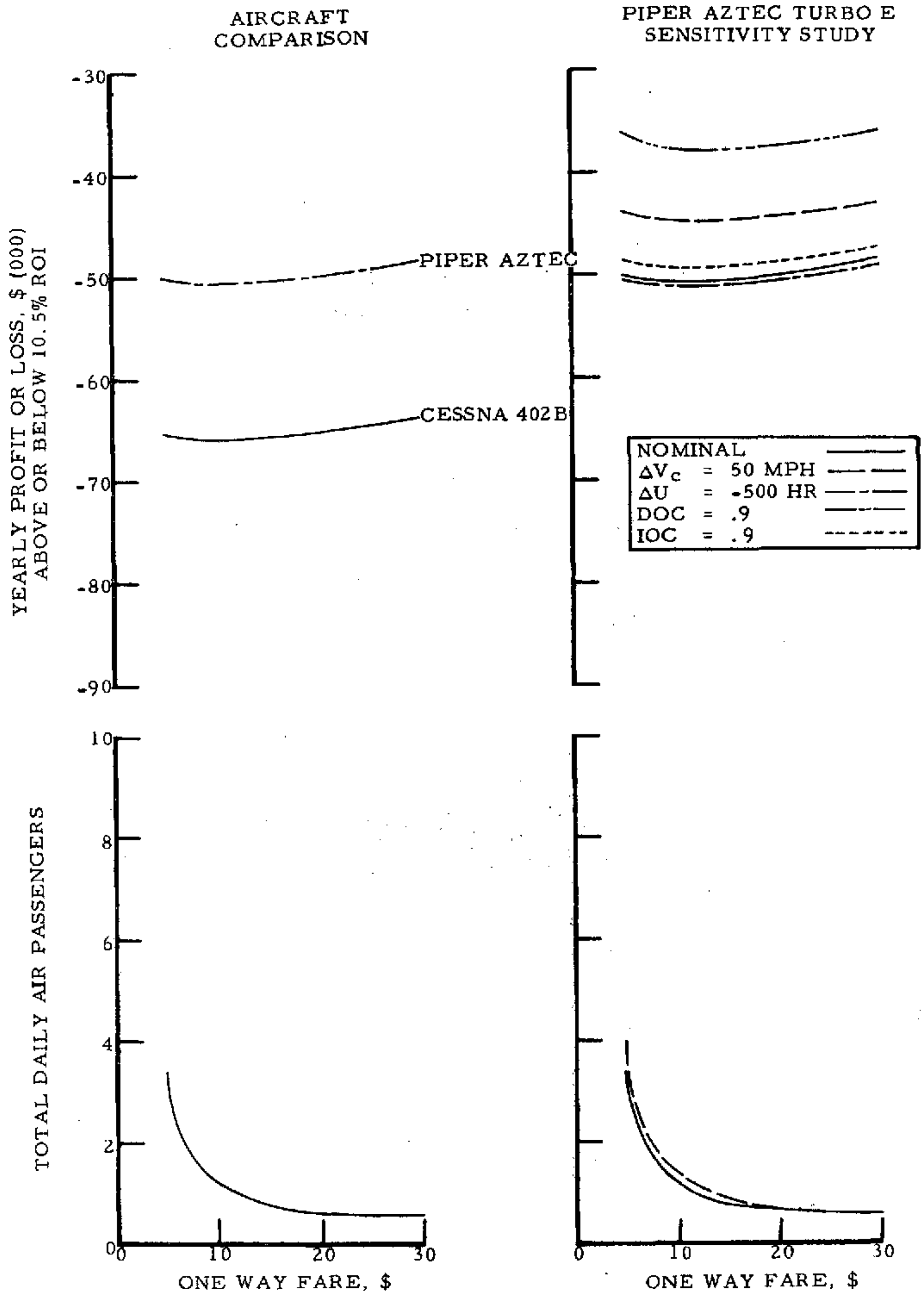


Figure 63. Parkersburg-Clarksburg

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attracting so many Ft. Huachuca passengers that the remaining space on the plane comes at too high a premium for the Willcox passengers.

It seems, therefore, that the "demand" passenger concept will work, but at the expense of the nominal self sufficient nonstop route passengers. New questions are raised, then, that remain to be studied, which deal with the alternatives of trading off passenger flow between cities such that economically viable air service is maintained but that the best interests of the passengers and the arenas are maximized.

7. ARIZONA AND WEST VIRGINIA ARENAS SUMMARY

An evaluation summary of the Arizona arena indicating daily air passengers, number of aircraft, fleet size, return on investment, and aircraft investment costs for each of the five aircraft is shown in Table 42. In making the evaluation of the various routes, the highest consideration was given to maximizing the number of passengers served at the lowest possible fare and that operating profits were maximized (or losses minimized). The summary comparison is based on this criteria.

This comparison indicates that the Cessna 402B and Piper Aztec aircraft could serve all Arizona city pairs at better than a 10.5% return on investment. The Beech 99A shows a relatively low return on investment while the Twin Otter and Swearingen Metro could not be utilized economically for service on most of the routes. The Cessna 402B and Piper Aztec aircraft investment costs are also well below those for the other aircraft although their fleet size is considerably higher.

An analysis of the operational and economic characteristics of each aircraft serving all city pairs is shown in Tables 43 through 47. This analysis identifies for each city pair optimum fleet size, fare, round trips, daily passengers, load factor, utilization factor (fraction of 3,000 hours), and return on investment in accordance with the following criteria:

Table 42. Aircraft Evaluation Summary--Arizona Arena

Aircraft	Daily Air Passengers	Number Of Aircraft	Fleet Size	Return On Investment, %	Aircraft Investment (000)
Cessna 402B	1,703	24.04	26	25.9	$ 3,900
Piper Aztec Turbo E*	787	21.22	23	28.5	2,599
Beech 99A	1,509	11.27	13	3.4	5,915
Twin Otter	1,737	14.91	16	-16.2	8,800
Swearingen Metro	1,981	9.84	11	- 2.4	6,545

* Does not include service between Phoenix-Flagstaff and Phoenix-Globe, aircraft too small for route.